RESEARCH WORK OF THE INSTITUTION

1931—32

"By Diligent Investigation We Serve"

The "Gas Journal" Summary of the Reports to be presented at the Autumn Research Meeting of the Institution of Gas Engineers, November 1—2, 1932

INSTITUTION OF GAS ENGINEERS

Abstracts of Reports to be presented at the Autumn Research Meeting on Nov. 1 and 2 at the Institution of Mechanical Engineers

9th Report of the Gas Education Committee—1931-32

Administrative.

Increased familiarity with the complex regulations of the Education Scheme have resulted in, *inter alia*, much closer co-operation between the Institution and the District Gas Education Committees, the Educational Unions, the Technical Colleges, and the Teachers throughout the country.

The experience secured since the entire revision of the Scheme in 1929, has enabled a further revision to be made during the past year. The basis of the Scheme, however, remains the same, the only fundamental alteration being that the Diploma in Gas Engineering (Supply) has taken the place of the Diploma in Gas Supply, and will admit to Corporate Membership of The Institution of Gas Engineers, if the other conditions under the By-Laws are fulfilled. Candidates may continue to take the Diploma in Gas Supply at the Examinations in 1933, 1934, or 1935, and holders of that Diploma may apply to have it converted to the Diploma in Gas Engineering (Supply), if the additional Ancillary Subjects are presented not later than 30th June, 1935.

The duration of the Minor Course in Gas Works Practice has been increased from 2 to 3 years, to conform with the Minor Course in Gas Supply Practice. There is now no restriction as to the age of candidates for the Final Grade Examination in Gas Fitting. The remaining alterations in the Scheme deal with numerous matters of detail rather than with principle.

The Examinations held under the Education Scheme are definitely recognized as an essential part of the training of the Gas Engineer. Whilst Gas Engineers and Managers are encouraging the members of their Staffs to take the Educational Courses available, it is observed that the employees of Gas Contractors have not yet entered for the Examinations to any appreciable extent.

The Institution is continuously advising students as to their studies, and the District Gas Education Committees are anxious to help all those interested in the Scheme.

Examinations, 1932.

There was an increase of 37 per cent. in the number of candidates examined in 1932, as compared with the number in 1931. Thus, 310 candidates sat in 1931 and 426 in 1932, but these figures may be increased to 349 and 481 respectively by adding the number of candidates who secured passes in the Examinations, but whose names are not published herein for the reasons given in a prefatory note to the Results. Candidates were examined at a large number of Centres throughout Great Britain and in New Zealand and South America.

The Charles Hunt Memorial Medal in the Diploma Examination in Gas Engineering for 1932 was awarded to J. H. Dyde, M.Sc., Assoc.M.Inst.Gas E. (Plymouth), and the first Charles Hunt Memorial Medal in the Diploma Examination in Gas Supply for 1932 was awarded to Lionel Poulter (London).

In regard to the Minor Courses in Gas Works Practice and Gas Supply Practice and in Gas Fitting, the number of candidates for the Examinations in Gas Supply Practice and Gas Fitting shews an increase of 37 per cent. and 35 per cent. respectively over the preceding year.

The Report of the Board of Examiners on the 1932 Examinations indicates the necessity for a good general education, and emphasizes the inability of many candidates to answer Questions clearly and concisely and to sketch properly. The standard of work submitted by the Diploma Candidates in Gas Engineering and the Candidates in the Ordinary and Higher Grade Examinations in Gas Supply shewed improvement.

Teachers' Course, 1932.

A Teachers' Course in Gas Engineering and Gas Supply—organized by the Board of Education and conducted by Mr. C. H. Creasey, H.M.I.—was held from 4th to 8th July, 1932, at the Westminster Technical Institute, London, S.W. 1. Of the forty, Graduates and other, Teachers in attendance, thirty-seven were from England and three from Scotland. The Teachers were invited to the Meeting of the Gas Education Consultative Committee, in the Council Chamber of the Institution, at which matters of interest to all concerned in the Education Scheme were discussed.

Approved Courses.

The following additional Major Courses were approved

by the Board of Education and the Gas Education Committee during the year:—

3 Courses in Gas Engineering—Ordinary Grade.
3 Courses in Gas Engineering—Higher Grade.
2 Courses in Gas Supply—Ordinary Grade.
1 Course in Gas Supply—Higher Grade.

The following additional Minor Courses were approved by the Gas Education Committee during the year:

2 Courses in Gas Works Practice.
4 Courses in Gas Supply Practice.
15 Courses in Gas Fitting.

Examinations, 1933.

The next Examinations in Gas Engineering will be held on 29th April, 1933, and in Gas Supply on 6th May, 1933. Entries must be received by the Secretary of the Institution not later than 28th February, 1933.

Notification of an External Candidate's intention to present himself for examination in a Subject ancillary to Gas Engineering or Gas Supply must now be received by the Secretary not later than 15th January in each year.

Students are reminded that 1933 is the final year for the examination of candidates who have been given "Permission to Sit" in previous years with qualifications which are now inadequate. Students have to comply with the Regulations in force at the time of their Examination, and "Permission to Sit" is given only in respect of the Examination to be held next after such permission is granted.

THE INSTITUTION OF GAS ENGINEERS.

LIST OF DISTRICT GAS EDUCATION COMMITTEES.

District.	Chairman.	Secretary.
Eastern	A. Gregory	E. F. Keable, Engineer and Manager, Gas Works, Southtown, Great Yarmouth.
Irish	J. D. Smith	G. Airth, Gas Works, Dundalk.
Lancashire	W. J. Smith, B.Sc.	J. Alsop, Gas Street Gas Works, Bolton.
Midland	F. C. Briggs	H. R. Hems, Gas Department, Council House, Birmingham.
North of England	C. Dru Drury	H. Lees, J.P., Gas Office, Hexham.
Scottish	—	David Fulton, Gas Works, Helensburgh.
Southern (S.E.)	D. C. Cross	T. H. Prater, Gas Works, Margate.
Southern (S.W.)	R. Robertson	S. Hole, 32, Devonshire Buildings, Wellsway, Bath.
Wales	H. D. Madden	O. Thomas, Gas Works, Pentre, Rhondda.
Yorkshire	J. Bridge	J. W. Horwill, Gas Department, Town Hall, Bradford.

1st Report of the Gasholder Sub-Committee

Inspection and Insurance of Gasholders

In June, 1931, an Insurance Company promoted a Scheme to provide not only for Insurance against damage arising from Gasholder accidents—which risk was already largely covered by the existing "Fire" and "Third Party" Policies of Undertakings—but for the carrying out of an Initial and an Annual Inspection of the Gasholders insured. Similar Schemes for the Inspection and Insurance of Gasholders were afterwards promulgated by other Insurance Companies.

The Gasholder Sub-Committee collected and collated information relative to these Schemes and at its meeting on 10th November, 1931, it was resolved to advise the Council of The Institution of Gas Engineers to recommend where local conditions and circumstances make it advantageous for Gas Undertakings to provide by contract for the Inspection and Insurance of Gasholders, that such Inspection and Insurance should conform with Model Conditions approved and issued by the Institution.

At further meetings of the Gasholder Sub-Committee on 21st March and 5th and 25th April, 1932, developments were reported and information was received as to the further inquiries made on its behalf. The whole subject was fully considered, and it was resolved further to advise the Council in accordance with the terms of this Report.

The Gasholder Sub-Committee is of opinion that Undertakings should continue to be responsible for the Inspection of their Gasholders by their own Staffs and if and when an Inspection by a third party appeared desirable, such Inspection should be arranged for by the Undertaking as is generally done for other Plant.

To facilitate the Inspection of Water-Sealed Gasholders by the Staffs of Undertakings, the Sub-Committee recommends that such Inspection should be carried out and recorded—*mutatis mutandis*—in accordance with the "Periodical Gasholder Inspection and Maintenance Record" and the "Annual Gasholder Inspection and Maintenance Record."—See "JOURNAL" for July 20, 1932.

The Insurance of Gasholders under the Inspection and Insurance Schemes aforesaid does not appear to be generally necessary, having in mind the extreme remoteness of the "risk." Where, however, local conditions and circumstances make it advantageous for Gas Undertakings to provide by such contracts for the Inspection and Insurance of their Gasholders, regard should be had to the considerations enumerated in the "Memorandum on the Insurance of Gasholders."—See later.

It is deemed inopportune to publish Model Conditions for inclusion in Policies for the Insurance of Gasholders, until adequate experience of the Schemes for such Insurance has been obtained.

It is not considered desirable to recommend the Council to give official recognition to the Policy of any one Insurance Company, believing it to be in the best interests of Undertakings that Companies should be free to compete for this class of business and for Undertakings not to be restricted in their choice of Companies.

It is necessary to differentiate between the Inspection of Gasholders and their Insurance. Insurance as such would not ensure the safety of Gasholders; it would merely operate to transfer a financial liability from an Undertaking to an Insurance Company. The Institution of Gas Engineers has urged and will continue to urge the necessity for the adequate Inspection and Maintenance of Gasholders. The Home Office is similarly concerned, but there is no information, direct or indirect, that that Department attaches importance to the Insurance of Gasholders.

If a Scheme for Inspection cum Insurance is in fact attractive in certain cases by reason of the Annual Inspection provided, it should be remembered that

such a Scheme does not remove the necessity for frequent Inspection and Maintenance by the Undertaking itself and that advantageous arrangements for the Annual Inspection could probably be made with a third party if and when required, without the necessity for entering into a Policy of Insurance.

MEMORANDUM ON THE INSURANCE OF GASHOLDERS.

1. (*a*) In considering the adoption of a Scheme for the Inspection and Insurance of Gasholders, regard should be had, in the opinion of the Gasholder Sub-Committee of The Institution of Gas Engineers, to the extent to which the Gasholders are or could be covered, at normal premiums, by existing Policies, such as Third Party and/or Fire Policies. Further, it should be observed that Insurance Companies will naturally desire to minimize the "risk" and if the work specified in the Inspection Report is not carried out, the Policy may not be renewed, whilst liability in the case of an accident might be disclaimed.

(*b*) The impression appears to be that the proposed Premiums are high, but it has to be remembered that the cost of an adequate Inspection and Report is substantial and the "risk" (although remote) is a new one, which the Insurance Companies cannot at present accurately assess. After the first few years the Premium on a Policy should be considerably reduced; consequently, lengthy agreements should be avoided, so that the Premium and the terms of the Policy can be revised.

2. (*a*) The Scheme is likely to prove more attractive to smaller Undertakings, since larger Undertakings have the necessary facilities for carrying out their own Inspections and for meeting the consequences of accidents, which in the case of Gasholders are extremely rare. It has been suggested, however, that this immunity from accidents may not continue and that the comprehensive Inspection of a Gasholder is a matter for an expert specializing in that kind of work.

(*b*) It is with a view to meeting the possible requirements of the larger Undertaking that one Insurance Company is prepared to formulate a Modified Scheme, in cases where Gasholders of recent date are under skilled supervision and the Inspection of the Insurance Company would entail unnecessary expense.

(*c*) Another Company is prepared to accept the Certificate of the Gas Engineer of the Undertaking concerned for the purpose of the Insurance of its Gasholders. This course is economical and would commend itself to Gas Engineers who dislike the principle of an Inspection from outside; especially when such Inspection is carried out by Gasholder Contractors, subject only to the supervision of the Consulting Engineer to the Insurance Company. In the case of Insurance on such a Certificate, the Policy should be free of limitations as to liability if there is any fault whatsoever in the said Certificate of the Engineer, who for the purpose of certifying should be regarded as the agent of the Insurance Company. Some Undertakings might find it convenient to provide that the Certificate of a Consulting Gas Engineer approved by the Insurance Company, shall be accepted instead of the Certificate of the Gas Engineer of the Undertaking concerned.

3. A Policy for the Inspection and Insurance of Gasholders should be as free from limitations as it is reasonably possible to make it, since the "risk" is a remote one and is only likely to occur as a result of unusual circumstances and conditions.

The Policy, in which the term "Gasholder" should be deemed to include the Tank, if any, should provide for:—

I. The ANNUAL EXTERNAL INSPECTION of the Gasholder and the submission of a WRITTEN REPORT thereon.

If after the INITIAL INSPECTION, the Insurance Company is not prepared to cover the Gasholder, the Undertaking should not be liable for the cost of the Inspection, unless it desires a Written Report, when it should be required to pay a reasonable fee.

II. INSURANCE against any or all of the following optional "risks":—

(*a*) DAMAGE TO THE GASHOLDER AND THE OTHER PLANT AND PROPERTY of the Undertaking resulting from Gasholder accidents and breakdowns of all kinds whatsoever.

i. Repairs necessitated by "FAIR WEAR AND TEAR" would not be covered, but this exception should not extend to accidents or breakdowns resulting fortuitously from "Fair Wear and Tear."

ii. The risk of damage to the Gasholder from FIRE should not be excluded, unless this "risk" is already fully covered by an existing Fire Policy on the Plant and Property of the Undertaking. In this connection it should be remembered that it might be difficult to determine if a Gasholder accident or breakdown was the cause or the result of Fire. Hence the necessity for cover against all Fire contingencies.

iii. The Gasholder should continue to be covered when in a CONTRACTOR'S HANDS for repairs.

iv. Damage resulting from RIOT, CIVIL COMMOTION, AND WAR RISKS would normally be excluded, but damage generally described as due to an ACT OF GOD (*e.g.*, Earthquakes) should be fully covered.

v. The PREMIUM should be assessed on the merits of each Proposal for Insurance, as judged by the situation, conditions and circumstances of the Undertaking and by the Initial and subsequently the Annual Inspections. A MAXIMUM LIABILITY would normally be provided for under each heading of cover and up to the first £20 or thereabouts of any Claim would generally be borne by the Undertaking. Care should be taken to ensure that the maximum cover is adequate.

(*b*) LIABILITY TO THIRD PARTIES for damage to Persons and Property.

i. An EXISTING THIRD PARTY POLICY covering the Plant and Property (including the Gasholder) of the Undertaking may provide for this liability, which might result from an accident or breakdown of the Gasholder or other Plant. Such Policies frequently extend to ACCIDENTS OCCURRING ON THE DISTRICT in connection with pipes and the fixing of apparatus, due to accidents or breakdowns or the fault or negligence of the employees of the Undertaking.

ii. Cover should extend to any LEGAL COSTS incurred by the Undertaking as a result of a Third Party claim.

(*c*) LOSS OF GAS, assessed on the nett cost into holder.

In the case of some Undertakings an accident to a Gasholder and/or its Plant, might result in the closing down of the Works until the damage is made good, but there is no information that cover can be effected by an Undertaking against LOSS OF REVENUE in such an event and for such a period.

(*d*) Liability for DAMAGE FROM AIRCRAFT.

Undertakings in the vicinity of an aerodrome or situated in proximity to a recognized air route, should insure against the "risk" of suffering damage to Gasholders from aircraft, but since such cover should extend to the whole of the Plant and to Third Party liability, it would probably be found convenient to provide for this "risk" in a separate Policy. The "risk" normally being exceptionally remote, the Premium should be very small.

Planning of Gas Installations to Conform with the British Standard Specification for Street Lighting

F. C. SMITH

This paper, which was presented at the Conference of the Association of Public Lighting Engineers in September last, and a lengthy abstract of which was published in the "JOURNAL" for Sept. 21, outlines a method of deciding the type of lamp and orientation of light sources to be employed, while methods are suggested of obtaining the additional information required to be submitted with the tenders. Of this information the most important is the light distribution of the sources employed and the distribution of illumination on the road which would result from their use.

The paper includes the results of a number of tests on typical gas lamps carried out in the Watson House Laboratories of the Gas Light and Coke Company, together with the results obtained with two new reflectors specially evolved during the work. It also includes a series of curves, plotted from simple formulæ which enable the candle-power required, and the angles at which it must be directed, to be read off for any particular arrangement of the lamps. A number of street lighting schemes which have been produced by applying the method outlined in the paper are set out. These would afford practicable methods of lighting streets 30, 40, or 50 ft. wide to levels of illumination represented by Classes C to H of the British Standard Specification for Street Lighting. In addition some information regarding the demonstration Class A Lighting in Whitehall in 1931 is given.

A basis is suggested for prescribing the class of illumination necessary for a given type of thoroughfare. It shows in what degree the gas lighting of certain well-known London streets conforms with this basis.

Second Report on the Back-Run Process for the Manufacture of Carburetted Water Gas

Research Chemist: F. J. DENT, Ph.D. *Research Assistants:* W. H. BLACKBURN, Ph.D., N. H. WILLIAMS, M.Sc., E. PARRISH, M.Sc.Tech., and A. R. KELLY, B.Sc.

Tests have been made on a plant at the Nine Elms Works of the Gas Light and Coke Company, first arranged so that part of the steam entering the generator was highly superheated, and secondly, so that all of it was saturated.

The plant had been erected by Humphreys & Glasgow, Limited, and, working with a blast pressure of 20 in. water gauge at the base of the generator, its rated capacity for 500 B.Th.U. gas was 1,750,000 cu.ft. per day. The set was hand-operated, equipped with a self-clinkering grate, and generator and waste heat boilers. It should be emphasized at this point that the figures given in the Report were obtained on a plant with a water sealed generator and may require modification for other types.

During the tests, the generator was charged with coke at the end of every 26 minutes, an allowance of 1 minute being made for the operation. The remaining 25 minutes were split up into five-minute cycles, the nature of which in any coking-to-coking period was identical.

In the first series of tests the steam which passed downwards through the fuel bed was superheated to approximately 700° C. before entering the top of the generator. It was supplied to the top of the superheater, and flowed down this chamber, up the carburettor, passing into the generator *via* the short carburettor to generator main. The blue gas produced during this portion or phase of the cycle was led directly from the base of the generator to the wash box. Throughout the Report this method of steaming is referred to as "back-run" steaming, and a cycle in which it is included as a "back-run" cycle.

In the second series of tests the steam which passed downwards through the fuel bed was supplied saturated to the top of the generator. The blue gas produced left the base of the generator and was taken to the top of the carburettor, passing down the latter and up the superheater on its way to the wash box. This method of steaming is termed "down-run" steaming, and cycles of which it forms a part, "down-run" cycles. Where in the Report, it is necessary to refer to steam passing in a downward direction through the fuel bed, irrespective of whether it is superheated or not, the term "downward" steam is used.

Because of the nature of the process, the blue gas formed during the back-run cannot be enriched in the normal manner by means of oil; carburetting is limited to the up-run. The down-run cycle is at an advantage in this respect, as it places no similar restriction on the supply of oil and lower rates of injection can be used if desired. It would be anticipated that the importance of this advantage would depend on the calorific value of the gas made and, accordingly, tests were carried out on both back-run and down-run cycles, (*a*) making gas of 390-400 B.Th.U. per cu.ft., and (*b*) making gas of 490-500 B.Th.U. per cu.ft.

The results obtained in these comparative tests are given below:—

Test 1	..	Approx. 490	B.Th.U. gas	..	Back-run cycle
Test 2	..	,, 390	,,	..	Back-run cycle
Test 3	..	,, 490	,,	..	Down-run cycle
Test 4	..	,, 390	,,	..	Down-run cycle

(*a*) *The Efficiency of Blue Gas Production.*

The results of the tests shewed that the relative efficiencies of blue gas production depended mainly on two factors.

The first was the heat returned to the generator as superheat in the back-run steam and, to a lesser extent, as heat in the gases formed by gasification of material deposited from the oil on to the chequerbricks of the carburettor and superheater. This return of heat, which was present only in the back-run tests, led to a reduction in the coke consumption as a result of the decreased amount of heat to be generated in the fuel bed during the blow, for the formation of a given volume of gas during the run.

The second factor was the ability to maintain an optimum condition in the fire. This was largely determined by the proportion of the steam supplied which could be passed in a downward direction through the fuel bed. Within the limits of working used during the tests, it was found that the greater the proportion of downward steaming used, the higher was the temperature in the lower zones of the fire, and the greater the efficiency of generating heat in the fuel bed during the blow periods.

It may be noted that, if for the maximum blue gas efficiency there is an optimum temperature for the lower zones of the fuel bed, this temperature was not exceeded

the tests, where the highest temperature used was limited by consideration for the mechanical grate.

In the down-run tests, the amount of downward steam was restricted by the difficulty which arose in igniting the blow gases in the carburettor, a difficulty which increased with the calorific value of the gas prepared and also with the amount of down-run steam used. The supply of down-run steam, by cooling the top of the fire, led to a low temperature of the gases leaving the generator at the start of the succeeding blow, and the ignition of these gases was further retarded by a low temperature of the chequerbricks at the top of the carburettor, resulting from the absorption of heat at this point during the period of oil injection, and from the additional cooling in the down-run by the blue gas entering from the base of the generator. It is clear that the difficulty would be accentuated when injecting large amounts of oil in the preparation of gas of high calorific value. This was found to be so, and in Test 3 the amount of down-run steam which could be used was less than in Test 4. As a result, the poorer fuel bed conditions in the former test, led to lower efficiency.

Owing primarily to the transfer of heat from the superheater to the carburettor by the back-run steam, the difficulty of igniting the blow gas was absent in the back-run tests on gas of either high or low calorific value, and, if the time of oil supply was limited, it was possible to use more downward steam than in the down-run tests. Indeed, the amount of steam used in this way could be increased until the upper limit of temperature for the safe working of the mechanical grate was reached. Under such conditions an optimum performance of the generator was obtained.

The generator was so worked in Test 2, the back-run test on low calorific value gas, and the influence of the improved condition of the fuel bed, combined with the economies effected by the return of heat in the back-run steam, led to a considerable reduction in the coke consumption.

Test No.	2	3	4
	Back-Run.[1]	Down-Run.	Down-Run.
Coke consumption, dry, in lbs. per 1000 cu.ft. blue water gas	36·7	41·3	40·5

[1] For comparative purposes it may be noted that a coke consumption of 36·7 lbs. per 1000 cu.ft. of *blue* water gas, when expressed per 1000 cu.ft. of *carburetted* water gas, approximately corresponds to :—

35·3 lbs. when making gas of 350 B.Th.U.
33·8 ,, ,, ,, ,, 400 ,,
32·2 ,, ,, ,, ,, 450 ,,
30·6 ,, ,, ,, ,, 500 ,,

It is seen that the coke consumption per 1000 cu.ft. of blue gas was greater by 12·6 per cent. in Test 3 and by 10·3 per cent. in Test 4, than that in the back-run Test 2. The high efficiency resulting from back-run steaming in Test 2 was obtained when making gas of low calorific value (390 B.Th.U. per cu.ft.). The efficiency should not be regarded, however, as being attainable only when preparing gas of this calorific value. The results obtained in the generator are applicable to gas of any calorific value, so long as the quantity of oil to be injected does not reduce the effective use of back-run steaming. In the 5-minute cycle used in Test 2, oil was supplied at a rate of 5·6 gallons per minute over a period of 73 seconds. This time could have been increased to at least 78 seconds if required,[2] by shortening the clearing period and purge. It follows that, using the same amount of back-run steaming as in Test 2, and preparing gases of various calorific values, the rates of oil injection would be as follows:

Calorific Value.	Rate of Oil Injection.
400 B.Th.U. per cu.ft.	4·95 galls. per min.
450 ,,	7·60 ,,
500 ,,	10·75 ,,

These figures shew that at calorific values above 450 B.Th.U. per cu.ft. the oil rate becomes high, but not excessively so, indeed the corresponding figure for the test in the 27th Report of the Joint Research Committee was equivalent to 14·1 gallons per minute. The results of the tests suggest that the amount of oil supplied per run has considerably more influence than the increase in rate likely to be imposed by restricting the time of oil injection, and it is believed that the higher oil rates indicated above would not in themselves lead to appreciable loss of oil efficiency, if the temperatures of the cracking chambers were increased accordingly. It should be noted in this connection that the composition of the waste gases in Test 2 shew that there was a sufficient excess of heat in the blow gases to maintain a higher temperature in the carburettor and superheater if desired.

In Test 1, the back-run test on gas of 495 B.Th.U. per cubic foot, primary consideration was not given to the generator, and the cycle used was governed by the rate at which oil was supplied. This rate was 8·80 gallons per minute, and as a result the duration of the up-run was 124·4 seconds, leaving only 44·2 seconds for back-run steaming, as compared with 88·7 seconds in Test 2. Under these conditions, it was not possible to maintain as high a temperature in the lower zones of the fuel bed. As a consequence, the temperatures in the middle of the fire became unduly high, the percentage of carbon-dioxide in the blow gases diminished, and the economies, arising from the return of heat to the generator by the back-run steam, were lost as a result of the poorer efficiency of "blowing." The coke consumption in this test was 41·9 lbs. per 1000 cu.ft. of blue water gas, *i.e.*, 14·2 per cent. higher than in the other back-run Test 2.

(*b*) *The Rate of Gas Production.*

A greater make of blue gas per day was obtained in the back-run Test 2 than in either of the down-run tests. The figures cannot be compared directly, however, as the rate of air flow through the fuel bed during the blow periods was not the same in each case. The rate in Test 2 was higher than in Test 3 by 0·5 per cent. and lower than in Test 4 by 5·6 per cent. Since there is no reason to suppose that the variations in the rate of air flow were connected with the nature of the cycles used, and were probably caused by small differences in the coke or in the depth of the fuel bed, it is better to compare the tests on the basis of an equal rate of air flow. When this allowance is made, the daily make of blue gas in the back-run Test 2 was greater by 9·7 per cent. than in the down-run Test 3, and by 6·9 per cent. than in the down-run Test 4. (Direct comparison of the figures reported gives 9·9 per cent. for Test 3 and 4·5 per cent. for Test 4.)

The greater make obtained in Test 2 was mainly the result of two factors, namely, (*a*) the heat returned to the generator by the back-run steam reduced the amount to be raised by "blowing," and (*b*) the somewhat greater rate at which the heat was generated in the blow, as indicated by the higher percentage of carbon dioxide in the blow gases, and their lower temperature as they left the generator.

It will be noticed that in the back-run Test 1, the advantage of back-run steaming was again lost. In Test 1, the make of blue gas per day was 6·6 per cent. less than in the other back-run Test 2 owing, firstly, to the lesser amount of heat returned to the generator by the smaller quantities of back-run steam used, and secondly, to the relative inefficiency of blowing.

When considering the increase in efficiency and rate of blue gas production brought about by the use of back-run steam, it should be realized that the two increases are interconnected. For example, comparing Test 2 with Test 4, the use of back-run steaming increased the efficiency of blue gas production from 50·0 per cent. to 54·2 per cent., under conditions in which the make of gas per day was simultaneously increased by 6·7 per cent. By a general lowering of the fuel bed temperature it is probable that the efficiency could have been still further increased if the gain in "make" had been sacrificed, or, *vice versâ*, a still higher make could have been obtained, if the increase in efficiency had not been sought for.

(*c*) *The Steam Supplied to Set.*

The amount of steam supplied to the set per 1000 cu.ft. of blue water gas was rather greater in the back-run

[2] This time was obtained by assuming a clearing period of ten seconds. Ten seconds for the clearing period should be regarded as a maximum. When using back-run steaming, it is probable that the clearing period can, with advantage, be reduced to 2 to 3 seconds, since any oil remaining on the chequerwork would not be lost but would be vaporized and cracked in the fuel bed during the back-run. With a clearing period of such duration the time available for oil injection is increased still further to 85 seconds, corresponding to gas with a calorific value of 480 B.Th.U. per cu.ft.

than in the down-run tests. All the steam supplied did not pass through the fuel bed; some was lost by leakage, condensation at the base of the generator, and, in the case of Tests 1 and 2, steam was lost in the carburettor and superheater at the change over from the back-run to the purge. The greater amount of steam supplied in the back-run tests was not however due to the steam lost at the end of the back-run. This item was more than counterbalanced by the leakage at the hot gas valve in the down-run tests. The increase in the steam consumption in Test 1 was accounted for by condensation, while in Test 2, owing to the absence of difficulties caused by low temperatures in the carburettor, it was possible to pass steam through the fuel bed at a somewhat greater rate, a factor which no doubt contributed to the higher rate of blue gas production in this test.

The total steam requirements of the set and auxiliary plant were approximately the same for back-run and down-run tests on gas of similar calorific value. In the back-run tests, as noted above, an increased amount of steam was supplied to the set, but the increase was negatived by a reduction in the consumption of the turbo-fan, resulting from the smaller amount of air supplied during the " blow " periods.

Test No.	1	2	3	4
	Back-Run.	Back-Run.	Down-Run.	Down-Run.
Steam to set, in lbs. per 1000 cu.ft. blue water gas	41·2	42·5	40·4	40·8
Steam to auxiliary plant, in lbs. per 1000 cu.ft. blue water gas	41·3	36·0	42·2	38·4
Total steam requirements, in lbs. per 1000 cu.ft. blue water gas	82·5	78·5	82·6	79·2

(*d*) *The Steam Raised in the Generator and Waste Heat Boilers.*

In a general way it can be stated that the amount of steam raised in the generator boiler per 1000 cu.ft. of blue gas made, decreased with increasing rate of gas production, but, as would be anticipated, the performance of the boiler was influenced by the distribution of heat in the fuel bed. The amount of steam raised was lowest in Test 2, where it equalled 32·6 lbs. per 1000 cu.ft. of blue gas made, *i.e.*, 72 per cent. of the steam supplied to the generator for gas making. It was highest in Test 3, at 38·3 lbs., which, in this test, was equivalent to 95 per cent. of the steam supplied to the generator.

The coke consumption of the generator was influenced by the amount of heat passing into the boiler, and accordingly the efficiency of gas production was reduced as the amount increased. The heat used to raise steam in the boiler was approximately equal to one-half of the heat absorbed from the generator by the gas-making reactions.

When considering the generator as a blue water gas producer, account should be taken of the steam raised in the generator boiler. This is done most directly by subtracting from the total coke supplied to the generator, the coke which would be used in an independent boiler with the same steam-raising performance as the generator boiler. The difference between these two quantities of coke is then comparable with the coke consumptions of generators, not equipped with an annular boiler. The tests gave the following figures.

It was not customary at Nine Elms to use tertiary air to complete the combustion of the waste gases before they entered the waste heat boiler. As a result, if small differences in specific heat be neglected, the amount of steam raised in the boiler was governed by the volume and temperature of the gases leaving the top of the superheater during the blow periods. The volume of the waste gases depended mainly on the efficiency of the generator, decreasing as the efficiency increased. The temperature of the gases was governed by that of the chequerwork at the top of the superheater, and was therefore higher when making gas of high calorific value and was reduced by the use of back-run steaming. Thus the amount of steam raised was greatest in Test 3, using a down-run cycle to prepare gas of high calorific value,

Test No.	1	2	3	4
	Back-Run.	Back-Run.	Down-Run.	Down-Run.
Coke (dry) to generator, in lbs. per 1000 cu ft. blue water gas	41·9	36·7	41·3	40·5
Steam raised in annular boiler, in lbs. per 1000 cu.ft. blue water gas.	36·4	32·6	38·3	35·1
Coke, required by an independent boiler, to raise the same amount of steam as was raised in the generator boiler, in lbs. per 1000 cu.ft. blue water gas.	4·4	4·0	4·6	4·3
Coke consumption of generator, making allowances for the steam raised in generator boiler, lbs. per 1000 cu.ft. blue water gas	37·5	32·7*	36·7	36·2

* This coke consumption per 1000 cu.ft. of *blue* gas corresponds to the following consumptions, when expressed per 1000 cu.ft. of *carburetted* water gas :—

At 350 B.Th.U. per cu.ft. = 31·4 lbs.
400 " " " = 30·1 lbs.
450 " " " = 28·7 lbs.
500 " " " = 27·3 lbs.

Note.—In Table XXIII, page 161, similar figures are expressed per 1000 cu.ft. C.W.G.

and smallest in Test 2, on low calorific value gas, when most back-run steam was used.

Test No.	1	2	3	4
	Back-Run.	Back-Run.	Down-Run.	Down-Run.
Steam raised in waste heat boiler, in lbs. per 1000 cu.ft. blue water gas.	44·7	31·2	56·7	46·9

The performances of the boiler during the tests are only characteristic of the condition stated, namely, when no tertiary air is used. They are not representative of the total steam-raising possibilities of the various gas-making cycles, since both the potential and sensible heat of the waste gases can be used for steam raising if desired. For this reason, the following figures were calculated for the amounts of steam which would have been raised, if the waste gases had been completely burnt before entering the boiler.

Test No.	1	2	3	4
	Back-Run.	Back-Run.	Down-Run.	Down-Run.
Steam raised in waste heat boiler, assuming complete combustion of waste gases, in lbs. per 1000 cu.ft. of blue water gas	87·5	63·6	87·3	89·6

The figures are based on the assumption that the temperature of the gases leaving the boiler were not influenced by the use of tertiary air. They are sufficiently accurate, however, to shew that the amount of steam raised would be considerably increased if tertiary air were used.

The short table given below shews how far the amount of steam raised in the generator and waste heat boilers met the requirements of the generator and auxiliary plant. It is seen that in both down-run tests, more steam was raised than was required. This was not so in the back-run tests, and an amount of steam, considerable in Test 2, was drawn from an independent source.

If, however, all the potential heat in the waste gases had been liberated before they entered the boiler, an excess of steam would have been raised in all the tests.

Quantities of Steam in Lbs. per 1000 Cu.Ft. of Blue Water Gas.

Test No.	1	2	3	4
	Back-Run	Back-Run.	Down-Run	Down-Run.
Total steam raised in generator and waste heat boiler	81·1	63·8	95·0	82·0
Total steam raised, assuming complete combustion of waste gas	123·9	96·2	125·6	124·7
Total steam supplied to generator and auxiliary plant	82·5	78·5	82·6	79·2
Steam obtained from independent source	1·4	14·7	*Nil*	*Nil*
Steam raised in excess of total requirements, assuming complete combustion of waste gas	41·4	17·7	43·0	45·5

(e) The Efficiency of Oil Cracking.

The yields of oil gas, expressed in " therms per gallon of oil," were as follows:—

Test No.	1	2	3	4
	Back-Run.	Back-Run.	Down-Run.	Down-Run.
Calorific value	495	390	491	395
Yields of oil gas, therms per gallon of oil.	1·23	1·35	1·26	1·33

The figures shew that a greater efficiency of oil cracking was obtained when making gas of lower calorific value, but there were only small differences between the efficiencies in back-run as against down-run tests when gas of the same calorific value was made. The results indicate that the disadvantage of the back-run in restricting the time available for oil injection, was largely counterbalanced by the more uniform temperature in the carburettor and superheater. It should be emphasized however, that the yields for the down-run tests were obtained only by special supervision of the plant. The difficulties encountered in these tests in maintaining an adequate temperature in the carburettor and superheater, have already been referred to and, in the absence of the supervision, it is probable that a smaller proportion of down-run steam would have been used in order to obtain a more stable condition in the carburettor. Decreasing the down-run steam, however, would have reduced the efficiency of blue gas production to a figure below that reported for Tests 3 and 4.

(f) General Conclusions from Tests 1 to 4.

The comparison of back-run and down-run steaming leads to the following general conclusions.

The introduction of back-run steaming can be used to obtain a reduction in coke consumption, or an increase in the volume of gas made per day, or both. The test using a back-run cycle unrestricted by the time occupied by oil injection (Test 2), shewed a reduction in coke consumption of 3·8 lbs. per 1000 cu.ft. of blue water gas, together with an increase of 6·9 per cent. in the volume of gas made per day, when compared with the test on a down-run cycle making gas of 390 B.Th.U.s per cu.ft. Comparing the same back-run test with the down-run test on gas of 490 B.Th.U.s per cu.ft., the corresponding figures were, a reduction in coke consumption of 4·6 lbs. and a 9·7 per cent. increase in the make of gas per day.

The cycle used in this back-run test could be employed to make gas up to a calorific value of at least 450-460 B.Th.U. per cu.ft. without appreciable loss in the efficiency of oil cracking. When making gas of higher calorific value than this, a compromise must be made between the possible gains in the performance of the generator and the reduction in the efficiency of oil cracking brought about by the higher rate of oil injection. In the back-run test reported for gas of 490 B.Th.U. per cu.ft., Test 1, such consideration for carburetting was carried too far, and the increase in efficiency and throughput of the generator were lost. It is believed, however, that the advantages of back-run steaming, shewn by the comparison of the two tests on low calorific value gas, would have been present to a similar extent in this test on gas of 490 B.Th.U. per cu.ft. if:

(*a*) the time available for back-run steaming had been increased by using a slightly higher rate of oil injection and shorter purge and clearing periods; and

(*b*) if the rate of back-run steam supply had been raised, irrespective of the percentage of it which was decomposed, until the highest permissible temperature was attained on the grate pyrometer.

Against the advantages of back-run steaming must be set the reduction in the amount of steam raised in the boilers, particularly the boiler on the waste gas stream. In the test where full use was made of back-run steaming, the amount of steam raised in the boilers was less by 18 lbs. per 1000 cu.ft. of blue water gas. If it were necessary to replace this steam, using an independent boiler, an expenditure of 2·35 lbs. of coke would be required. In the case of a plant in which tertiary air was used, the introduction of back-run steaming would give rise to the greater reduction of 28 lbs. in the amount of steam which it is possible to raise, an amount equivalent to 3·65 lbs. of coke.

Report on Gases Met with Underground

The Holborn Explosion of 1928

Prof. J. S. HALDANE, C.H., F.R.S.

You are well aware of the destructive explosion which occurred in December, 1928, under the Holborn roadway in the old pneumatic tube used by the Post Office for taking telephone cables underground. In some way this tube had got full of an explosive mixture, which was ignited by a Post Office servant who had lit a naked light, not suspecting an explosive mixture. A Commission of Inquiry was appointed, and they presented a very illuminating Report. One of the main questions on which they had to give an opinion was whether the combustible gas was coal-gas from a leak in a main, or had some other source. Although, as a Gas Referee, I could not appear as a witness for the Gas Light and Coke Company, in whose District the explosion occurred, I volunteered, after consulting my colleagues, to give what evidence I could, on behalf of the Gas Industry generally and of London gas consumers, on whom a decision of the Commissioners might impose heavy costs. The question of damages was quite amicably settled out of Court as between the Post Office and the Gas Light and Coke Company, so that no trace of friction on this subject remains. I think, therefore, that the occurrence may be referred to in the present purely scientific paper.

Roughly speaking, the case for the Post Office was that it was impossible to account for the explosive gas except through an escape of lighting gas; and that on previous occasions quite large proportions of coal-gas had been detected in the tube by means of the Short's indicator. In order to prevent injury by water to the cables, the manhole ventilators which had previously existed at intervals along the tube were abolished, and the new manholes kept closed air-tight except when men had to go in. Through keyholes in the ventilators, after removing the stuffing, the air in the tube could be tested with the indicator. Before men went in, fresh air was blown through the tube with an electric fan, and it was while a man was entering the tube on a dark December morning to connect a plug supplying the fan with current that the explosion occurred.

The case for the Gas Company was that no smell of escaping gas had been noticed anywhere along the street before the explosion; that no appreciable leakage could be found in any main left intact after the explosion; that the smell noticed by the workmen was, with one exception of an inexperienced man, described by them as that of " sewer gas," meaning by this a smell suggestive of putrefaction; and that consequently they did not suspect any danger of explosion. It appeared, therefore, that the gas might have been due to anaerobic fermentation in the soil in consequence of leakages from old drains, &c., and the air-tight roadway and foundations preventing oxygen from diffusing down.

In giving evidence, I pointed out that during the night preceding the explosion there had been a steady and considerable fall in barometric pressure, and that under these circumstances, as shewn by the experiences with wells with which I have been associated, large volumes of gas may be driven into any underground space communicat-

ing with the open air, as the tube did at its end, and that this might contain combustible gas from anaerobic fermentation. I could not take the matter further at the time; but a certain amount of further evidence appeared later, or was obtained from experiments made by the chemical staff of the Gas Light and Coke Company. The Commissioners, however, concluded, for reasons given in their Report, that this further evidence would be irrelevant, and they came to the conclusion that the explosive gas must have been coal-gas which had leaked into the tube.

I am bound to say that on reading their clear and excellent Report on the circumstances of the explosion itself and of observations made on the air or gas in the tube during the years preceding the explosion, I can see no justification for the definite conclusion of the Commissioners that the explosion was due to coal-gas rather than gas from anaerobic fermentation, so I am taking this opportunity of reviewing their reasons.

They first point out very correctly that it would have taken about 2000 cu.ft. of anaerobic fermentation gas to produce the explosion, and that on the theory that the issue of gas was due to the fall of barometric pressure which occurred just before the explosion a vastly greater quantity of the gas must have been present in the subsoil, which seemed to them very improbable. If, however, they had consulted my Paper on the gases in wells,* they would have seen that enormous volumes of gas or air may issue on a fall in barometric pressure. I also quote measurements made by Mr. T. Fairlie on the so-called blowing wells near Northallerton. He found that with a rise of 0·4 in. of barometric pressure an inflow of twelve million cubic feet of air occurred into one well where he measured the inflow. It is true that combustible gas from anaerobic fermentation in ordinary subsoil had never, so far as I know, been reported previously as causing risk of explosion; but this might be due to its never having been looked for. In the light of the Holborn explosion, it seems to me quite probable that the sewers, where their walls are permeable to gas, constitute an underground ventilation-system for subsoil gases, including combustible gases. If so, the well-established custom of good ventilation of every sewer is doubly justified. It was owing to there having been an explosion in an abandoned sewer which had been left unventilated, that, by direction of the Holborn Borough Council, ventilators had been established for the tube before the Post Office took it over. Combustible gas may be present in the subsoil in large amounts under anaerobic conditions, and may find ready vent through an open excavation rather than directly to surface.

The Commissioners, to my great astonishment, proceeded to argue that because borings made along the line of the explosion, several weeks after the surface had been freely exposed to air, shewed no approach to anaerobic conditions, these conditions cannot have existed either there or anywhere else in the neighbourhood, and that therefore analyses made by the Gas Light and Coke Company's chemical staff, shewing that hydrogen (not methane) was formed in the subsoil under anaerobic conditions, were irrevelant, as well as the further evidence which I offered to give them; so that the anaerobic gas theory could be excluded with certainty. This reasoning seems to be totally unsound, as oxygen would penetrate rapidly into the subsoil when the surface was exposed to air. This would account for the presence of abundant free oxygen in the layers of sand, &c., below the tunnel-site, and absence of evidence of existing anaerobic fermentation.

I now come to the evidence as to coal-gas having been found previously in the tube. While I think that on the whole such analyses as were made, and the fact that there were persons who thought that at one time or another they had smelt coal-gas, makes it probable that a very little coal-gas was sometimes present in the tube, as it very probably would be in the soil surrounding the tube, I distrust entirely the apparent evidence which was obtained by applying the Short indicator to the key-holes of manholes after removing the air-tight stuffing. This very useful indicator, which is a development of the Ansell indicator, originally designed, though without much real success, for indicating fire-damp in mines, is practically an indicator of the hydrogen in coal-gas. It therefore, does not distinguish between coal-gas and hydrogen from other sources. The Commissioners recount various occasions on which large proportions of coal-gas were apparently found with the indicator. It is mentioned, for instance, that as much as 27 per cent. was found at the manhole where Shaftesbury Avenue crosses Holborn High Street. On looking through their list it appears that when any gas was found it was almost invariably at this manhole that the indications were noticed or were strongest. Now beneath this manhole a shaft had been sunk for the purpose of carrying telephone cables underneath an adjoining sewer. This seems by far the most likely place for anaerobic fermentation gas from the deep subsoil to enter the tube: in which case the gas would go straight up to the cover of the manhole. Various other indications seem to point to the same place as a point of entry for gas, which might easily reach this offshoot of the tube through porous layers of sand or gravel with relatively air-tight layers of clay, soil, or other material above them.

While I fear that the actual source of the gas which exploded in the Holborn accident will never be settled conclusively, I hope that future research will throw light on how far anaerobic conditions exist in subsoil and give rise to anaerobic fermentation on a large scale when organic matter is present.

Coal Gas.

With actual escapes of coal-gas in sewers I have some acquaintance, as while I was investigating sewer air I once detected one, and had no difficulty in doing so by smell. I also assisted in investigating an accident from a gross gas escape where a sewerman and a fireman who had gone to the rescue, with one of the early defective rescue apparatus, were both killed by carbon monoxide poisoning. Actual escapes of coal-gas underground, together with the means of dealing with them and the precautions needed in doing so, are, however, so familiar to members of the Institution of Gas Engineers that I need hardly mention the subject.

It is perhaps fortunate that in the presence of free oxygen the gases formed in anaerobic fermentation, as well as carbon monoxide, are readily consumed by other micro-organisms, and thus tend to disappear when they reach oxygenated soil. If, therefore, there is free oxygen in soil at the level of ordinary gas-mains and service-pipes, very small leakages from them are probably of not much concern; but here, also, research is needed.

Bitumen Gas.

Closely related to the subject of underground escapes of coal-gas is that of gas-escapes caused by bad short-circuits in old-fashioned electric mains. There are still, I think, a good many electric mains which, with the idea of obtaining greater safety from short-circuits, were laid in troughs filled with bitumen. Experience has shewn, however, that after a number of years they are apt to develop short-circuits which, when they get so far as to melt and then distill the bitumen, are apt to cause such a great and rapid evolution of gas as to be very dangerous under the circumstances. Owing to the manholes being closed air-tight, the only ready means of escape for gas is into houses. In one case of this sort, on which I held jointly an inquiry at Acton, the gas had penetrated into a house along the earthenware pipe carrying the electric service. In some way—apparently by sparking—the gas was ignited where it issued into the air, and an explosion followed which completely wrecked the house, killing one person and very seriously injuring another. The inmates had been alarmed by the smell of the gas, and had made certain that there was no fire or light in the house. They had also, before the explosion, opened both front and back doors of the small house, to let the gas out; but apparently there was enough explosive mixture at a level above the top of the doorway to cause the great damage. Although the gas had been turned off at the meter the latter was badly damaged and the escaping gas set alight, so that it was suspected at first that the explosion was one of coal-gas. With the general adoption of safer methods of insulation, accidents of this kind, which have occurred again and again, will, I think, disappear.

* Haldane, Trans. Inst. Mining Engineers, 1896, Vol. XI., p. 265.

2nd Report of the Liquor Effluents and Ammonia Sub-Committee

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EFFLUENTS.

The Liquor Effluents Sub-Committee was appointed in 1926 to investigate the methods which might be adopted for minimizing the production of gas liquor effluents or for rendering such effluents suitable for discharge into public sewers or into rivers. The most important effluent from Gas Works is spent liquor from the distillation of ammoniacal liquor, but in those cases where the recovery of ammonia has ceased to be practised the ammoniacal liquor itself must be regarded as an effluent.

The most obvious way of disposal of a liquid effluent produced in inland towns is by way of the local sewage works, where it is purified to a considerable extent and then is admitted to the natural waterway of the district. The amount of purification required by a works effluent can be regarded as a measure of its undesirability in the sewage. The test most commonly employed to determine this is that of "oxygen absorption," being the parts of oxygen absorbed in 4 hours at 80° Fahr. by 100,000 parts of liquor from an acid solution of potassium permanganate. Spent liquors from Gas Works give values of the order of 500 to 1000, whilst domestic sewage averages about 10. It does not follow, however, that the relative difficulties of purification of these liquors are proportional to these figures, since the oxygen absorption is only a very rough measure of the amount of oxygen required in the biochemical oxidation which takes place at the sewage works, and it gives no indication of the ease with which this oxidation occurs. This is a point which is engaging the attention of this Sub-Committee at the present time.

Four types of substances present in spent liquor account for almost all its oxygen absorption from potassium permanganate; these are phenols, higher tar acids, thiosulphates, and thiocyanates. The last two are present as calcium salts if the liquor has been limed; otherwise they occur combined wih ammonia. In so far as any of these bodies can be removed from, or prevented from occurring in the liquor, the oxygen absorption will be reduced, and the liquor improved from the effluent point of view. The Sub-Committee has given considerable attention to this aspect of the problem, and has concentrated more particularly on (*a*) the prevention of higher tar acids from occurring in the ammoniacal liquor, and (*b*) the recovery of phenols from ammoniacal liquor. By either of these methods the toxicity of the effluent liquors is decreased.

Higher Tar Acids.

Higher Tar Acids occur mainly in liquor from continuous vertical retorts, and demand attention not only because of their oxygen absorption, but because they produce strongly coloured compounds on partial oxidation, thus causing discoloration of sewage or stream. The source of these bodies is the tar which condenses with the liquor, and it has been found that they can be eliminated almost completely from the liquor by the separation of the tar from the gas whilst above the dew point. An electrostatic tar precipitator was found to be most effective, but good results were also given by a cyclone tar extractor and hot liquor sprays in the foul main. It is, of course, essential that the liquor produced by such methods of operation should not be allowed subsequently to come in contact with the tar. Liquor which is used in the retort house, or which condenses there, will remain rich in higher tar acids, and if allowed to mix with the rest of the liquor increases the oxygen absorption of the latter; this should, if possible, be avoided. As far as practicable therefore condensation of liquor in the retort house should be prevented.

Phenols.

It is unfortunately the case that the complete elimination of higher tar acids from ammoniacal liquor is accompanied by some increase in the phenol content. Phenols, however, are not so objectionable in liquor as are higher tar acids, since they do not form coloured compounds on atmospheric oxidation, and they are more easy to remove from the liquor. Various methods have been proposed for accomplishing this removal, and the one which has met with most favour involves the washing of the liquor with benzole and the recovery of the phenols from the benzole either by distillation or by washing with caustic soda solution. Several plants of this type have been erected in Germany and in the United States of America, but only one is at present in operation in this country, although at least one other is contemplated. An investigation reported in the 1st Report of the Liquor Effluents and Ammonia Sub-Committee shewed that for efficient purification the washer should be of considerable height and the liquor should be heated. It was concluded that the process could not normally be made profitable unless some economical means of recovering the benzole dissolved in the liquor were employed. At Partington, Manchester, active carbon is used for this purpose.

In this connection a reliable method of estimating benzole contained in liquor is obviously necessary. The Committee has worked out a method depending on the absorption of the benzole by active carbon. During the investigation it was found that benzole is present in ordinary ammoniacal liquors in very small quantities depending on the temperature at which the liquor had been in contact with the gas.

Tricresyl Phosphate as Solvent.

Another solvent used for the recovery of phenols is tricresyl phosphate, which has advantages over benzole in its low volatility and solubility in water, and its great capacity for dissolving phenols. An investigation into its use is reported. The tricresyl phosphate was contained in an experimental washer, and ammoniacal liquor at 60° C. was passed through the solvent, samples of the outgoing liquor being taken from time to time. The initial efficiency of the tricresyl phosphate was much greater than that of benzole, and its total capacity for phenol was eight times that of the lighter solvent. In addition, thirty times the quantity of higher tar acids was removed. The phenols recovered from the tricresyl phosphate were of better quality than those obtained from benzole, but there is reason to fear that the solvent would deteriorate with continued use, even if vacuum distillation were employed for the recovery of the phenols. The difficulty seems to be that distillation does not recover the higher tar acids, which tend to decompose in the solvent, rendering it more viscous and therefore less suitable for washing purposes.

The Committee is indebted to the I. G. Farbenindustrie, of Frankfort, for information concerning the process. Two plants of capacities of 100,000 gallons and 20,000 gallons per day respectively are in operation in Germany. The phenol content of the liquors treated is 3 to 5 gm. per litre, and the percentage purification is 92 to 95. The liquor is washed with 8 to 10 per cent. of its volume of

solvent, and the amount of the latter which is lost is stated to be 0·08 gm. per litre of liquor, which with tricresyl phosphate at 1s. 6d. per lb. represents one shilling and twopence per 1000 gallons of liquor. The working temperature is 20-30° C.

In order to come to a definite decision as to which solvent is the more economical to use it would be necessary to compare full-scale plants operating on English gas works liquor. The greatest single factor operating against tricresyl phosphate is the initial cost of solvent.

Tar Oils as Solvents.

Work has been done on tar oils as solvents for purifying ammoniacal liquor. Samples of tars were distilled and the distillates dephenolated and fractionated. Fractions of various boiling ranges were tested and found to be superior to benzole in their solvent power for phenols and higher tar acids. There was no great difference between the fractions; in practice an oil would probably be chosen which is sufficiently lighter than liquor to render separation rapid, and which boils at a higher temperature than phenols, so as to allow of the latter being recovered by distillation. It was found that basic substances were to a large extent the cause of the high solvent capacity of these oils for phenols, for after shaking with acid the distribution coefficients were reduced by approximately half, to that of benzole. These basic substances were gradually removed on shaking with water, the solvent thereby deteriorating, but to what extent this would take place with liquor, which itself contains basic substances, is not at present known. Neither is information yet available as to how the solubility of these substances compares with that of benzole, but here again the amount dissolved by ammoniacal liquor would not be so great as that dissolved by water. The liquor is probably already in equilibrium with such oils, since they constitute part of the tar, in which case there would be little loss. This aspect of the problem presents a promising field for further investigation.

Thiocyanate.

The thiocyanate in liquors arises mainly from the reaction of oxygen with ammonium sulphide and cyanide in contact with liquor. Its formation can therefore be minimized by reducing the quantity of oxygen in the gas or reducing the time of contact of the gas with liquor. It has been shewn that when the gas is passed through tower scrubbers where it is in contact with liquor for upwards of three minutes, the amount of thiocyanate formed is very much greater than when the gas is washed in rotary scrubbers where it remains only a few seconds. In the former case the quantity of thiocyanate formed diminished when the oxygen in the gas was reduced.

Washing the gas with liquor rather than with water also has the effect of increasing the thiocyanate content of the liquor, and in one or two extreme cases the oxygen absorption due to this substance alone has been over 1000, instead of the normal 100 to 200, the increase being due almost entirely to prolonged washing of the gas with liquor.

Although the quantity of thiocyanate in an average liquor is considerably less than that of phenol, it may prove to be of equal importance because of the difficulty of its oxidation by bacteria. It has been established that in the bacteria beds at the Coventry Gas Works the thiocyanate in the liquor is destroyed to a much smaller extent than is phenol.

Thiosulphate.

This substance appears to be of only minor importance in liquor, since in quantity it is always less than thiocyanate, and it seems to be much more easily oxidized.

Bacterial Oxidation.

Even if spent liquor is improved by any of the methods just mentioned, it still contains substances with a considerable oxygen absorption. In most cases further purification of the liquor takes place at the local sewage treatment works. The bacterial oxidation of spent liquor has therefore always been in the forefront of the Sub-Committee's programme of research.

An opportunity has been provided at the Coventry Gas Works of following the experiment of purifying the spent liquor in comparatively concentrated solution in bacteria beds situated at the Gas Works itself. Results have been set forth in previous Reports. The bacteriology of the system has been examined in collaboration with Dr. F. C. Happold, who, with Dr. A. Key, has written a Paper on the subject, in which the organism which has been found to oxidize phenol is described. The purification on the Coventry beds when spent liquor is treated is about 80 per cent., and this has been sufficient to afford considerable relief to an overburdened sewage works. The liquor, after purification, however, has an oxygen absorption of the order of 100, and is therefore very far from being suitable for discharge into a stream. The process can only be regarded as one of preliminary purification, taking its place alongside those for the removal of phenol. As such it is decidedly expensive, both in capital expenditure and running costs. The Committee considers that if bacterial purification is employed, it should preferably take place entirely at the Sewage Works, as this would probably be more efficient and more economical than if undertaken partly at the Gas Works and partly at the Sewage Works.

The Committee was fortunate in being able to report the work of Mr. F. R. O'Shaughnessy on the purification of sewage which contained spent liquor (4th Report of the Liquor Effluents Sub-Committee). It was found that at Cheltenham up to 1 per cent., or more than twice the average rate of production, of spent liquor could be added to the sewage without serious deterioration of the effluent from the sewage disposal works. It was considered important that the liquor should be added regularly, and not in flushes. This point is rightly insisted upon by many sewage works managers.

It does not necessarily follow that the results obtained at Cheltenham are applicable to other Works, since so many different conditions may operate. Each Works therefore should be considered as a separate problem. It is a fact, however, that spent liquor is being treated at many sewage disposal works to the satisfaction of everybody concerned. The Committee feels that much could be accomplished by closer co-operation between the industry and those in charge of sewage treatment works. With this in view a Paper has been read by Dr. A. Key at a meeting of the Midland Section of the Association of Managers of Sewage Disposal Works.* A lively and sympathetic interest was shown by members of the Association.

Other Methods of Disposal.

The disposal of spent liquor by running it into the sea is practised at most seaside towns, where it is usually mixed with the town's sewage. The sea affords dilution much in excess of that required to render the liquor innocuous.

Another way of disposal of the liquor is by evaporation, either into the base of chimneys, or on the bars of producers, or in boilers utilizing waste heat. These methods are most suitable for devil liquor which leaves no solid residue. The residue from spent liquor may or may not be objectionable depending on where the evaporation takes place. If the evaporation can be accomplished without the consumption of more fuel than is normally used, then the cost of the process is practically zero. At Hinckley, for instance, it was found that 15 gallons per ton of coal carbonized of mixed devil and spent liquor could be evaporated on the bars of the producers by replacing with liquor the water usually used for cooling purposes. To evaporate any liquor in excess of that replacing the water normally supplied would be expensive

* "Gas Journal," April 12, 1932.

in fuel unless an abundance of waste heat or unsaleable coke breeze were available.

Ammonia.

The Ammonia Sub-Committee was instituted in 1928 to explore the present position and future prospects of the commercial production of sulphate of ammonia or other ammonium salts from gas works liquor. The Committee issued three Reports before it amalgamated with the Liquor Effluents Sub-Committee to form the Committee which now issues its Second Report.

A survey by Mr. H. Hollings and Dr. E. W. Smith of the position of by-product ammonia was included in the Third Report of the Ammonia Sub-Committee published in 1930, and so far as the general situation is concerned, the present Committee adheres to the conclusions there drawn. The fall of the price of neutral ammonium sulphate to as little as £5 5s. per ton has led to many gas undertakings ceasing to practise the recovery of ammonia, preferring to dispose of the crude liquor in some other way, usually by destruction. The methods employed are not always successful or cheap, and in some cases may give rise to nuisances. The Committee feels that this policy is not wise, and that the Gas Industry should still endeavour to maintain its position in the sulphate of ammonia market. It is considered that the present price of sulphate is artificially low, and that some improvement may take place in the future. It must also be borne in mind that the price of spent oxide, being governed to a large extent by the consumption of sulphuric acid, would probably fall still further as a result of a wholesale discontinuation of sulphate manufacture.

Economies in the manufacture of sulphate of ammonia as set out in the First and Third Reports of the Ammonia Sub-Committee are still possible, and if adopted may reduce considerably the cost of sulphate making. Attention is again drawn to the possibility of the establishment of centralized plants for the manufacture of ammonia products, individual gas undertakings supplying to these plants either concentrated liquor or some easily and cheaply prepared ammonium salt, such as ammonium bicarbonate. It should be pointed out that the production of concentrated liquor has now been made an entirely automatic process, the cost being no more than, if as much as, that of several processes for the disposal of ammoniacal liquor which have come before the notice of the Committee.

The destructive processes indicated above include the partial distillation of ammoniacal liquor into hot waste gas flues, the complete evaporation of the liquor, the evaporation of the liquor on the bars of producers, or into vertical retorts, the complete evaporation of the weakest fraction of the liquor, coke quenching, and various combinations of these. Where such methods of disposal are operated great care should be taken to avoid atmospheric pollution by obnoxious gases, such as hydrogen sulphide.

The Committee is investigating processes for the manufacture of ammonium bicarbonate, as being one possible way of cheapening the recovery of ammonia. This salt is comparatively stable, and it is hoped it will be possible to use it with advantage as a fertilizer. Plot trials of its fertilizing effect on wheat and potatoes are at present in progress; preliminary reports are satisfactory.

Biological Oxidation of Ammoniacal Liquor.

The question as to how easily ammoniacal liquor can be treated biologically, either at the Gas Works or at the Sewage Works, has been studied. It is known that in several places crude liquor is being treated successfully at the sewage works, but, so far as the Committee is aware, no detailed information has been published.

The important differences between crude and spent liquor are as follows:—

1. Ammoniacal liquor is of less volume than spent, but of greater concentration.
2. Ammoniacal liquor contains both free and fixed ammonia, whilst spent liquor contains either none at all or the fixed ammonia only.
3. Ammoniacal liquor contains sulphide equivalent to an oxygen absorption of 300 to 600 parts per 100,000, but this substance is usually absent from spent liquor.
4. Small quantities of other substances, *e.g.*, cyanides, neutral oils, and basic bodies, which occur in ammoniacal liquor, are not usually found in spent liquor. They may or may not have a marked effect on bacterial oxidation.

The total oxygen absorption of the ammoniacal liquor is roughly equal to that of the corresponding amount of spent liquor with the addition of that due to sulphide. The oxygen absorbing substances in spent liquor all occur in ammoniacal liquor, and therefore the conclusions drawn in the first part of the Report regarding higher tar acids, phenols, thiocyanate, and thiosulphate apply without modification to ammoniacal liquor as well as to spent liquor.

The results are given of changing over from spent to crude liquor on the bacteria beds at Coventry Gas Works. In spite of the decreased dose of liquor, the amount of purification accomplished was much reduced, being 50 per cent. compared with nearly 80 per cent. for spent liquor. The reduced bacterial activity was ascribed to the relatively large concentration of free ammonia in the liquor treated, this being fairly toxic to the life in the beds. This is a factor which presumably operates only where the liquor is purified without much dilution, and not when the liquor is mixed with 300 times its volume of sewage. The argument that the purification should take place at the sewage works rather than at the Gas Works is therefore considerably stronger when crude liquor is being considered. It must be borne in mind, however, that ammoniacal liquor may add a greater burden to the sewage works than does spent liquor, due partly to sulphide and partly to ammonia, which, although not contributing to the " oxygen absorption " as determined, requires oxygen to convert it to nitrate. It does not therefore necessarily follow in every case that a works which can deal with spent liquor can treat the corresponding amount of ammoniacal liquor. There seems, however, to be no reason why those in authority at a sewage works which already treats spent liquor should refuse to make a trial with ammoniacal liquor, provided that all parties agree to abide by the result of the test. In this connection the Liquor Effluents and Ammonia Sub-Committee is always willing to give advice and other assistance.

The Cheltenham Sewage Works is among those which can deal with ammoniacal liquor with comparative ease, as was shewn by Mr. F. R. O'Shaughnessy. The beds remained in excellent condition, and the final effluent was still quite good when the sewage contained 0·5 per cent. of ammoniacal liquor, this being considerably more than the average rate of production. There were, however, indications that with this amount the limit of the capacity of the beds to oxidize all the ammonia was being reached, since the ammonia content of the effluent had increased.

On the other hand, 0·2 per cent. of crude liquor proved to be an overdose at the Hinckley Sewage Works. Here, however, the liquor had a high oxygen absorption, and contained a very large quantity of thiocyanate, and would therefore have been difficult to oxidize in any case. With a dose of 0·1 per cent. the effluent has remained satisfactory. The investigation is a good illustration of the fact that sewage works cannot be compared quantitatively with one another, and also of the many variable factors which can influence tests made at such works. It emphasizes the necessity of making an extended test with both spent and ammoniacal liquors before coming to any conclusion as to whether they can be dealt with successfully or not. It is impossible to say definitely in advance what results such a test on any particular works would yield.

Report on the Conversion of the Potential Energy of Coal Gas into Radiant Energy

Dr. HAROLD HARTLEY, Chief Chemist, Radiation, Ltd.

This Report is confined to a consideration of the emission of infra-red energy by the Bunsen type of flame and the changes which can be effected by the insertion of solid bodies in the flame, or by the use of radiants as in the gas fire. The data is presented in three Parts subdivided into seven Sections.

The first three Sections, constituting Part I, treat of the direct radiation of energy by the flame itself.

The structure of the compound flame is first examined. Attention is drawn to the fact that the outer sheath is of wavy form so that the limits of visible combustion are not sharply defined. A diagram is included to indicate the form and dimensions of the stream of hot products passing away from the visible outer cone, as the heat radiated by these resultant gases provides the major portion of the total radiation from the flame. There are three other possible sources of the flame radiation, namely, the outer and inner visible cones, which are sheaths of flame, and the inter-conal gases. The effect of the primary-air/gas ratio on the dimensions of the inner cone is represented in a diagram for a London gas,[1] whilst data referring to other gases, together with the calculated flame speeds, are included in an Appendix. The shortest cone is attained with an air/gas ratio less than is required for complete combustion.

Section II is devoted to the calculation of the composition and thermal intensity of the gases leaving the inner cone for different primary-air/gas ratios. It is computed that these gases have a thermal intensity corresponding to 2950° Fahr. for an air/gas ratio of 2·4, and 3500° Fahr. for an air/gas ratio of 3·4.

In Section III the quality and the quantity of the radiation emitted are first examined. The relative magnitudes of the emission at 2·8 μ and 4·45 μ are shewn by spectra attained using a Smithells separator and are in qualitative agreement with the results to be anticipated from the calculation of the inter-conal gas composition made in Section II. The results of determinations of the energy radiated by particular Bunsen and Méker flames at different aerations are given in a graph, which also enables a comparison to be made with the results published by the late Professor Callendar in 1910 for a Méker burner. Except at the highest aerations the results recorded are somewhat higher than those reported by Callendar.

In the two following subsections the relative magnitude of the emission by the four sources mentioned earlier is considered, and the proportions of the energy radiated from within and without the outer cone are deduced from the experimentally determined variation in the intensity of the emission of radiation by different sections across a Méker flame. It would appear that about 85 per cent. of the total radiation comes from the hot products without the flame. It is deduced that in computing the thermal intensity of the gases leaving the inner cone, correction for radiation loss during combustion can be neglected.

Part II deals with the effect of inserting a solid in the inter-conal gases on the quality and quantity of the energy radiated. The extent of the increase in the emission is determined by the surface properties of the substance used, which also influence materially the quality of the energy radiated, as indicated both by spectral examination and by its ability to penetrate suitable screens. The possibility of further chemical reaction of the inter-conal gases in contact with the solid is considered, and it is shewn that the input of energy to the solid will not be increased materially either as the result of further oxidation of the inter-conal gases or shift in the water-gas equilibrium. Whilst the apparent surface temperatures recorded for rods heated by the flame would appear to conflict with an explanation of the emission results on a "forced convection" basis, the correction which has to be applied to allow for variation in the emissivity in the red may be considerable at the experimental temperatures. The results attained appear capable of explanation on the basis of possible variations in the emissivities of the heated solids. A large number of simple substances and mixtures has been examined, and a selection of results is given. Seven diagrams represent infra-red spectra for some of the heated bodies.

Part III deals with experiments made with the gas fire which have a bearing on the matters discussed in the earlier parts of the Paper. In Section V results are quoted of experiments made to test the effect of variation in the surface of the radiant on the radiant efficiency. A coating of uranium oxide increased, and of alumina decreased, the efficiency recorded.

At normal aeration of a gas fire burner (air/gas ratio of 2·3 to 2·7 on London gas) the inter-conal gases contain much CO and H_2, and it is obvious that the combustion of these gases may have an important bearing on the radiant efficiency attained. In Section VI the variation in the efficiency recorded at different aerations over a considerable range of consumption is given and some of the factors influencing the result are discussed.

The Report concludes with Section VII in which there are recorded the results of determinations of the relative proportions of energy radiated by the fire which come directly from the heated gases and from the solid radiators. Gaseous radiation accounts for not more than 10 per cent. of the total heat radiated, this radiation being only about one-third of that which would have been emitted by the freely burning flame.

The investigation viewed as a whole indicates:

(1) That whilst the energy radiated by a freely burning flame varies with the aeration, it emanates principally from the heated products of combustion.

(2) That when the amount of radiation is increased by inserting solids within the flame or by allowing the flame to burn within a solid mantle, the amount of the increase and the quality of the energy are determined largely by the surface properties of the solid used. The extent of the "surface effect" is much modified, however, by the shape of the radiator.

The use of a solid emittor in conjunction with the flame lessens the amount of energy radiated directly by the heated products of the flame combustion.

(3) That when the gas is burned within a radiant the flow of secondary-air and the completion of the combustion of the inter-conal gases of the Bunsen flame influence appreciably the radiant efficiency attained.

[1] "London gas" is employed to designate the Town's gas received at 15, Grosvenor Place, S.W. 1, from the mains of the Gas Light and Coke Company.

30th Report of the Joint Research Committee of the Institution and Leeds University

Report on the Sigma B.Th.U. Recorder

Research Chemists: JAMES W. WOOD, M.Sc.Tech., A.I.C., and F. J. DENT, Ph.D. *Research Assistants:* W. H. BLACKBURN, Ph.D., N. H. WILLIAMS, M.Sc., E. PARRISH, M.Sc.Tech., A. R. KELLY, B.Sc., and J. W. G. DAVEY, B.Sc.

The 30th Report of the Joint Research Committee of The Institution of Gas Engineers and Leeds University furnishes an account of a detailed examination of the Sigma B.Th.U. Recorder with special reference to its suitability for use as an official recording instrument under the Gas Regulation Act of 1920.

The sphere of application of the Sigma B.Th.U. Recorder is, in the main, that of indicating the extent of fluctuations in calorific value in the periods between tests with a non-recording calorimeter in the case of small and medium size undertakings where the advantages to be gained by the use of a more elaborate recorder would not be commensurate with the cost of installation and maintenance.

The fact that the present type of Sigma Recorder is capable of only a moderate degree of accuracy (± 2 per cent.), which may, however, be adequate for the purpose in view, is to a large extent counterbalanced by the robustness, simplicity, ease of installation, and low cost of the instrument.

The Sigma instrument gives a record of calorific value automatically corrected, within limits, for fluctuations in specific gravity of gas and in atmospheric temperature and pressure. It is, however, inferential in action, and must be checked and set at intervals by comparison with a Boys non-recording calorimeter, since the recorder itself is not provided with means whereby its readings may be verified.

The Sigma Recorder was first subjected to certain special tests in order to obtain information making possible a clearer understanding of the action of the instrument, and to be assured, before undertaking systematic tests upon it, that its adjustments complied with the requirements of its designer.

After the completion of these special tests, the recorder was subjected to a prolonged run (four months, divided into three periods) under typical testing-station conditions, using the town's gas supply of the City of Leeds Gas Department, with a declared calorific value of 470 B.Th.U. gross per cu.ft.

The leading points from the results obtained during this period are:—

(1) The preliminary governing was satisfactory for inlet pressures between 1·5 to 8 in. w.g., but the inlet pressure should preferably not fall below 2·5 in. w.g.

(2) The loading of the governors of the gas controller was in excellent agreement with that required by the theoretical considerations.

(3) For steady conditions of atmospheric temperature and pressure, the control for changing specific gravity of gas within the limits 0·4-0·6 (air = 1) was good, the gas rate only varying by ± 0·3 per cent.

(4) The correction for changes in atmospheric temperature and pressure was not complete, although compensation of a serviceable order was effected.

(5) The further the atmospheric temperature and pressure depart from those for which the gas regulator is exactly adjusted, and the further the specific gravity departs from 0·5, the less satisfactory will be the correction of gas rate for these variables with the present design of controller. For normal fluctuations, the error on this account should not exceed ± 1·5 per cent. in a period of one month.

(6) The gas rate may show a gradual diminution with time due to fouling of the valves and control orifice. It is difficult to make a definite statement on this point, as the trouble is apparently much influenced by local conditions. In Leeds, for example, the recorder could be run with confidence for a fortnight, but would require the governors cleaning at least once a month.

(7) Upon the regular fluctuations noted under paragraphs (4), (5), and (6) above are superposed erratic fluctuations of ± 0·2 to ± 0·3 per cent. (These are greater than the errors of determination of the gas rates.)

(8) In accordance with official requirements, the recorder chart is marked on a uniform scale of 1/10 in. for each 1 per cent. above or below the declared calorific value, with a time scale of ¼ in. per hour. The pen movements were practically proportional to the changes in calorific value, but were not quite of sufficient amplitude. The error on this account would not exceed 0·6 per cent. for a 10 per cent. deviation from the declared calorific value.

(9) When there was a change in calorific value of gas supplied to the instrument, 80 per cent. of the change was registered in about 5 minutes, but the new quality had to be maintained for about 45 minutes in order to register the full extent of the change.

(10) On a fluctuating supply the *average* value appears to be correct even though the full amplitude of the change may not be registered.

(11) The differences between recorded calorific value and check tests show somewhat greater differences than can be accounted for by imperfections in the gas control system. Deviations of as much as ± 2 per cent. have occurred within short intervals of time.

(12) Irregularities in recording, to the extent of 1 per cent. to 1·5 per cent. have been traced to fluctuations in the humidity of the gas passed through the controller. The gas should be in a definite hygrometric condition, either dry, or fully saturated with water vapour. In practice the latter will probably be secured with greater ease.

(13) Theoretically, the readings of the recorder should be influenced by changes in the ratio gross/nett calorific value of the gas supplied to it. Although the amount of water gas added to the town's gas supply in Leeds has at times reached 25 per cent., there has been no characteristic change in reading traceable to this cause. (The calorific value is 470 B.Th.U. gross per cu.ft., and the gas initially contains much water gas as the result of steaming in vertical retorts. The effect of further additions of water gas is therefore not so marked as with pure coal gas, or gases of higher calorific value.)

(14) Trouble has been experienced due to stoppages of the clock, but this is a matter which can be rectified.

(15) The instrument has an indefinitely long life, and the specimen under test shows no deterioration after eighteen months' use.

(16) The amount of attention necessary to keep the instrument in reasonable working order is small.

Conclusion.

The Sigma B.Th.U. Recorder is an inferential instrument, which, if properly installed and given the

amount of attention indicated in the Report, can, in general, be expected to indicate the gross calorific value of town's gas with an error of not more than ± 2 per cent.

Normally it should be cleaned and adjusted at intervals of 14 to 28 days.

Under the supervision of a Gas Examiner, the Sigma Recorder may be serviceable for indicating the changes in calorific value taking place between official testings, and in small and medium-sized undertakings, of securing greater uniformity of calorific value than would be possible without such instrumental assistance.

It is, however, a question if it is a sufficiently accurate instrument for its readings to be made the basis of penal action.

For Works purposes, where daily checking is practicable, the performance might be so far improved as to keep within ± 1 per cent. of the correct calorific value, provided there are no marked fluctuations in the composition of the gas.

32nd Report of the Joint Research Committee of the Institution and Leeds University

Test of the Intermittent Vertical Chambers at Croydon

Research Chemists: F. J. DENT, Ph.D. *Research Assistants:* W. H. BLACKBURN, Ph.D.; N. H. WILLIAMS, M.Sc.; E. PARRISH, M.Sc.Tech.; A. R. KELLY, B.Sc.

This Report describes a test on an installation of vertical chambers at the Works of the Croydon Gas Company. The characteristics of this type of plant are:—

1. **The capacity and depth of the individual units; each chamber is 21 ft. high and holds approximately 3·5 tons of coal.**
2. **Carbonization is an intermittent process, the chambers being filled and completely discharged periodically.**
3. **The chambers are charged and discharged by gravity.**
4. **Heat is recuperated from the waste gases by the secondary air.**

The plant thus resembles a continuous vertical retort setting in that the coal completely fills the cross-section of the chamber, and a horizontal retort setting in that coke is discharged hot and is quenched externally.

Compared with continuous vertical retorts on the one hand, the intermittent nature of the chamber process facilitates the carbonization of certain coals, while, in contrast to horizontal retort practice, the complete filling of the chambers permits of satisfactory steaming, allowing the calorific value of the gas to be controlled and an increased thermal yield to be obtained.

A further characteristic, which depends upon the static nature of the carbonization, is that, as the whole of the chamber is heated to carbonizing temperatures, the waste gases leave the combustion flues at a relatively high temperature; they are not continuously cooled by the incoming coal, as in some types of vertical retort. Moreover, on discharging the coke at a high temperature a further loss of heat is incurred, a loss which is avoided in continuous vertical retorts by internal quenching. Consequently the amount of heat which must be available in the combustion flues of the intermittent chambers is higher than the corresponding quantity which is necessary with continuous vertical retorts. In order to prevent this greater heat requirement leading to a high coke consumption in the producers, the plant is designed so that a considerable proportion of the heat in the waste gas is returned to the combustion flues in preheated secondary air.

The details of construction of the setting of intermittent vertical chambers on which the Test described in this Report was made were given by W. Grogono, M.Inst.Gas E., Engineer to the Croydon Gas Company, in a Paper[1] to the Southern Association of Gas Engineers and Managers, and a description of a similar plant was included in a Paper, "Intermittent Vertical Chambers and Coal and Coke Handling Plant at Southall," Communication No. 27 of the Institution of Gas Engineers, presented by J. S. Thorman, M.Inst.Gas E., at the 68th Annual General Meeting, 1931.[2] These two Papers give, in addition, results which illustrate the properties of this type of installation as a carbonizing plant.

Mr. Thorman's Paper includes figures for a variety of conditions of throughput and calorific value. The results demonstrate the extraordinary flexibility of the plant in make and quality of gas. The make was shewn to depend upon variations in the temperature of the combustion flues, with corresponding alterations in the duration of carbonization, while the quality depended directly on changes in the time and amount of steaming. When preparing gas of 510 B.Th.U. per cu.ft. it was found possible to reduce the volume of gas made per day from a maximum of 5,254,000 cu.ft. to 3,310,000 cu.ft., *i.e.*, a reduction of 37 per cent., and when making gas of 460 B.Th.U. per cu.ft. from 5,149,000 cu.ft. to 3,791,000 cu.ft., *i.e.*, a reduction of 26 per cent. Also an example is given in which the calorific value of the gas was progressively decreased from 550 to 450 B.Th.U. per cu.ft. during 15 hours. It was found that a high percentage of the steam supplied to the chambers was decomposed, even when the steaming period was prolonged, and attention is drawn to the low percentage of nitrogen in the gas, which under all conditions in the wide range investigated did not exceed 5·4 per cent. Comparison of the coke produced with cokes from other types of plant shewed that the coke from intermittent vertical chambers was denser and stronger than that from either horizontal or continuous vertical retorts.

Mr. Grogono, also, emphasizes the flexibility of intermittent chambers, and refers to the latitude in coal buying which they permit. He gives detailed figures for labour and capital costs and, in addition, the figures for 18 months' working. These results shew the steady performance of the plant for the whole period since it was first put to work. At Croydon the method of operation was rather different from that at Southall. To quote from the Paper " . . . the plant has been worked at medium temperatures with the desire of securing long life, and no effort has been made at any time to see what maximum results could be obtained." Thus although the tests at Southall included one on gas of a similar calorific value to that made at Croydon, the temperatures in the combustion flues in the latter case were lower by 120° C. at the bottom of the chambers and by 160° C. at the top.

None of the results previously published for tests on intermittent vertical chambers are sufficiently comprehensive for the preparation of chemical and heat balances, and it was thought desirable to make the available data more complete by the construction of such balances for this type of carbonizing plant, newly introduced into this country. This has been done in the Test which is described in the present Report. The Test was made on the plant at Croydon without interfering with the normal

[1] "Gas Journal," Dec., 1931, CXCVI, p. 608.

[2] "Gas Journal," June, 1931, CXCIV., p. 763.

operating routine in any way. The sole difference between the conditions of the Test and those reported by Mr. Grogono was in the higher temperatures used in the combustion flues. Since the presentation of the Paper by Mr. Grogono these temperatures have been gradually increased by 40° C. at the bottom of the chambers and by 70° C. at the top. The higher temperatures are now in regular use at Croydon. During the Test, which was of four weeks' duration, nothing occurred to interrupt the operating schedule, and the performance of the plant was remarkably constant throughout.

(*b*) Results of the Test.

Description of Plant.

The plant was erected by the Woodall Duckham Companies, and was first put to work in November, 1929. It consisted of one bench of 36 chambers, arranged in 6 settings, each with its own built-in producer and recuperators. The chambers were designed for the carbonization of Durham coals; they were built entirely of silica and were 21 ft. high, the minor axis was 8 in. at the top and 12½ in. at the bottom, the corresponding major axes being 9 ft. 7½ in. and 10 ft. respectively. Each chamber was equipped with gas offtakes at top and bottom, that at the top leading to a dry collecting main, while the bottom offtake, which was included to prevent the development of excessive pressures in the lower part of the chamber, was sealed in a hydraulic main. Both offtakes were closed during charging and discharging, and only the top offtake was open during the final stage of carbonization when steam was being admitted to the bottom of the chamber.

Before charging the coal, the lower 12 ins. of the chamber were filled with graded small coke. This coke pad supported the coal in the heated portion of the chamber and also provided a free exit for the gases to the bottom offtake.

On discharging, the coke fell into a coke skip which, running on rails beneath the chambers, rapidly conveyed it to a tower under which it was quenched by spraying with a predetermined quantity of water, 1·4 lbs. of water per lb. of coke.

The Test was made using Durham coals, and the calorific value of the gas prepared was approximately 550 B.Th.U.'s per cu.ft. The plant was operated on a 12 hour carbonizing period, steam being admitted to the chamber during the last 2 hours. The results are summarized in Table I.

The Coals Used.

The coals used were mostly first-class Durham from a variety of sources and had the average analysis given in Table II.

Table I.—*Summary of the Results of the Test.*

Average temperature of bottom combustion flues, ° C.	1300
Average temperature of top combustion flues, ° C.	875
Coal carbonized per day (average), tons	252·4
Coal carbonized per chamber per charge, tons	3·74
Moisture in coal, per cent. (dry basis)	2·35
Ash in coal, per cent. (dry basis)	6·85
Total inerts in coal carbonized, per cent.	8·98
Coke pad, cwts. per ton of coal carbonized	0·95
Steam supplied to chambers, per cent. by weight of coal carbonized	3·27
Supplied to producers—	
Dry coke, per cent. by weight of coal carbonized	13·05
Steam, lbs. per ton of coal carbonized	36·0
Water, lbs. per ton of coal carbonized	103·0
Gas made—	
Volume made per day (average), cu.ft., sat. 60° F. and 30 in.	3,616,000
Volume per ton of coal carbonized (average), cu.ft., sat. 60° F. and 30 in.	14,320
Calorific value (average), B.Th U. per cu.ft.	549·0
Therms of gas, per ton of coal carbonized	78·6
Coke made, dry (total coke *less* coke pad), cwts. per ton of coal carbonized	13·9
Coke for sale, dry (coke made *less* coke to producers), cwts. per ton of coal carbonized	11·3
Tar made, dry, gallons per ton of coal carbonized	13·35
Ammonia made, lbs. of ammonium sulphate per ton of coal carbonized	28·3
Volume of ammoniacal liquor made, gallons per ton of coal carbonized	29·4
Oz. strength of ammoniacal liquor	11·4
Steam raised in waste heat boiler, lbs. per ton of coal carbonized	465

Table II.—*Analysis of Coal (Dry Basis).*

Moisture, per cent.	2·35
Proximate analysis—	
Volatile matter	32·90
Fixed carbon	60·25
Ash	6·85
	100·00
Ultimate analysis—	
Carbon	79·60
Hydrogen	5·00
Sulphur	1·90
Nitrogen	1·70
Ash	6·85
Oxygen and errors (difference)	4·95
	100·00
Calorific value, gross, dry basis, in B.Th.U. per lb.	14,240

Table III.—*The Composition of the Gases Produced During the Steaming Period.*

Composition of Gases.							Steam Decomposed Per Cent.	Remarks.
CO_2.	C_mH_n.	CO.	H_2.	CH_4.	C_2H_n.	N_2.		
1	2	3	4	5	6	7	8	9
2·0	0·1	37·6	57·3	0·9	0·0	2·1	91·4	Completely carbonized, low shrinkage, good decomposition
2·8	0·0	37·3	57·5	0·4	0·0	2·2	88·8	
8·0	0·3	25·6	60·0	2·8	0·1	3·2	61·0	Carbonization incomplete
8·1	0·7	23·2	59·5	4·4	0·8	3·2	53·1	
7·9	0·1	26·1	62·0	1·0	0·0	2·8	61·3	Marked shrinkage
6·8	0·3	30·4	59·9	0·9	0·0	1·7	69·6	

Coke nuts were used for the coke pad. The weight of the pad per charge was 0·176 ton, which is equivalent to 0·95 cwt. per ton of coal carbonized.

Steam Supplied to Chambers.

The steam passing to the chambers was drawn from the superheated line leaving the waste heat boiler and was metered before being distributed along the bench. The steam entered the bottom of the chamber along both sides, the two steam connections each containing orifice plates of ¼ in. bore. With a pressure of steam behind the plates of 43 lbs., the amount of steam supplied was equivalent to 3·27 per cent. by weight of the coal carbonized.

72·5 per cent. of the steam which passed up through the chambers was decomposed. This figure is the average of a number of determinations which shewed considerable variations among themselves. It appeared that the percentage of steam decomposed depended primarily on whether or not the charge had been completely carbonized, and on the nature of the coal. A lower percentage of steam was decomposed when the charge had not been completely carbonized and with those coals which shrank markedly during carbonization with the

consequent formation of an easy by-pass for the steam. The influence of these factors can be seen in Table III, which gives examples of the composition of the gas produced, together with the corresponding percentages of steam decomposed. It is also apparent that the percentage of carbon dioxide in the gas produced decreased with increasing steam decomposition.

Experiments were made to determine the variation in the steam decomposition during individual steaming periods. The results obtained are given in Table IV.

TABLE IV.—*The Variation in the Steam Decomposition During Individual Steaming Periods.*

1	2	3	4
Time of sampling from commencement of steaming period, mins.	20	65	110
Steam decomposed, per cent.	90·0	88·5	85·5
Composition of gases produced—			
CO_2, volume per cent	2·1	2·9	4·4
C_mH_n ,, ,,	0·7	1·3	0·6
CO ,, ,,	40·0	40·3	40·2
H_2 ,, ,,	53·9	52·1	51·6
CH_4 ,, ,,	0·6	0·5	0·5
N_2 ,, ,,	2·7	2·9	2·7

The Gas Made.

Throughout the Test the plant more than maintained its rated capacity of 3½ million cu.ft. of gas per day. The daily make averaged 3,616,000 cu.ft. over the month, a figure which corresponds with a volume of gas of 14,320 cu.ft. per ton of coal carbonized. The calorific value of the gas was 549 B.Th.U.'s per cu.ft., and hence it follows that the thermal yield of gas amounted to the satisfactory figure of 78·62 therms per ton of coal carbonized. The average composition of the purified gas is given in Table average composition of the purified gas is given in Table V.

TABLE V.—*The Average Composition of the Purified Gas.*

CO_2, volume per cent.	1·82
O_2, ,, ,, ,,	0·26
C_mH_n, ,, ,, ,,	3·10
CO, ,, ,, ,,	10·55
H_2, ,, ,, ,,	55·28
CH_4, ,, ,, ,,	20·86
C_2H_6, ,, ,, ,,	2·32
N_2, ,, ,, ,,	5·81
	100 00
Value of "m" in C_mH_n	3·32
Specific gravity of gas (air = 1)	0·43

It is seen that both the carbon dioxide and the nitrogen contents of the gas were low. The actual percentage of nitrogen present in the purified gas was 5·81. Of this amount, 2·59 per cent. came from the air admitted for purification, leaving 3·22 per cent. as the nitrogen content of the gas in the retort house. The nitrogen balance of the coal supplied to the chambers shews that 1·17 per cent. of the nitrogen in the gas came from the coal, and accordingly, 2·05 per cent. of the total gas made represents nitrogen drawn into the chambers as air or waste gas.

The Coke Made.

The total coke discharged from the chambers represented the coke made from the coal, plus the coke pad. Making allowance for the coke pad, it was found that the weight of coke made was 13·90 cwt. per ton of coal carbonized. After deducting the coke supplied to the producers as fuel, 11·29 cwt. remained for sale. It may be noted that 89 per cent. of the coke made remained on a 1¼ in. fork.

It is seen from Table VI that the average volatile matter in the coke was 1·3 per cent. This figure is considerably lower than those reported by Mr. Grogono, namely, 5·8 and 3·3 per cent. for coke from the top and bottom of the oven respectively. The reduction in volatile matter is no doubt due to the increased temperatures now used in the combustion flues, and is a factor contributing to the higher thermal yield of gas obtained during the present Test; 78·63 therms per ton

TABLE VI.—*Analysis of Coke Made (Dry Basis).*

Constituent.	Per Cent.
1	2
Proximate analysis—	
Volatile matter	1·3
Fixed carbon	89·2
Ash	9·5
	100·0
Ultimate analysis—	
Carbon	87·6
Hydrogen	0·4
Sulphur	1·4
Nitrogen	1·1
Ash	9·5
Oxygen and errors (difference)	0·0
	100·0
Calorific value B.Th.U. per lb.	12,880

were obtained in the Test, compared with an average of 74·51 for the last 12 months given by Mr. Grogono.

As indicated previously, a 1¼ in. fork was used to separate the coke samples into large and small coke. The ash content of the large coke averaged 8·8 per cent. and of the small 13·1 per cent.

Tar and Ammonia.

13·35 gallons of tar were collected per ton of coal. Of this volume, 9·10 gallons were recovered at the circulating system in the retort house, 4·10 gallons at the condensers, and 0·15 gallon as tar fog leaving the condensers. The temperature at the point on the gas stream where condensate ceased to flow back to the retort house, but passed forward with the gas to the condensers, was 161° F.

The specific gravity of the retort house tar was 1·142 and that of the condenser tar 1·072.

The ammonia production of the plant per ton of coal carbonized was equivalent to 28·3 lbs. of ammonium sulphate in 29·4 gallons of liquor, *i.e.*, 29·4 gallons of 11·4 oz. liquor.

The Producers.

The amount of dry coke consumed in the producers was 2·61 cwt. per ton of coal carbonized, *i.e.*, 13·05 per cent. by weight. In addition, 36 lbs. of steam and 163 lbs. of water were supplied at the grate, both quantities being expressed per ton of coal carbonized. The dry composition of the producer gas is given in Table VII.

TABLE VII —*Composition of Producer Gas.*

CO_2, volume per cent.	4·52
H_2S, ,, ,, ,,	0·23
CO, ,, ,, ,,	29·01
H_2, ,, ,, ,,	9·10
CH_4, ,, ,, ,,	0·30
N_2, ,, ,, ,,	56·84
	100·00
Calorific value, B.Th.U. per cu ft.	124

Of the total amount of 199 lbs., 149 lbs. could be accounted for as hydrogen and water vapour in the producer gas leaving the fuel bed, and the remaining 50 lbs. were lost in the wet ashes and by draining from the bottom of the producer. A determination shewed that the water which drained away was approximately 10 lbs. per ton of coal carbonized, leaving 40 lbs. as the amount lost in the wet ashes at the cleaning of the fire.

During the Test, the weight of dry ashes and clinker collected was 16·01 per cent. of the weight of the coke supplied to the producers. All the cleanings from the fire were shaken over a ¾ in. square mesh sieve, and the material resting on the sieve was separated by hand into clinker and coke. The amount of coke recovered in this way formed 4·25 per cent. by weight of the coke supplied to the producer. No credit has been allowed for it, however, in the figures given for fuel consumption.

The average compositions of the waste gas, (*a*), as it entered the recuperator, and (*b*) as it entered the waste

heat boiler, after passing through the recuperator, are given in Table VIII, below.

TABLE VIII.—*Compositions of Waste Gas.*

—	Entering the Recuperator.	Entering the Waste Heat Boiler.
CO_2, volume per cent.	19·43	18·21
O_2, ,, ,, ,,	0·31	1·66
CO, ,, ,, ,,	0·71	0·44
H_2, ,, ,, ,,	0·13	0·02
CH_4, ,, ,, ,,	0·33	0·21
N_2, ,, ,, ,,	79·09	79·46
	100·00	100·00
H_2O vols. per 100 vols. dry gas		15·0

These two analyses do not appear very different, but they indicate that some air leaked into the waste gas stream in the recuperator, either from the secondary air flues or from the atmosphere. The volume of air leakage was 9·0 per cent. of the volume of dry waste gases at the inlet recuperator.

After passing through the recuperators the waste gases were collected and drawn by a turbo-fan through a waste heat boiler. The boiler was supplied with water which had been preheated, firstly by passing through the water cooled tie rods on the setting itself, and then through a heater fed by exhaust steam from the turbine.

Heat was supplied to the producers as coke and steam, and its distribution between the setting, waste heat boiler, and loss up the stack is shewn in Table IX below, where the heat quantities are expressed, firstly in therms per ton of coal carbonized, and secondly, as a percentage of the total heat supplied to the producers.

TABLE IX.—*Heat Balance of Producers and Waste Heat Boiler.*

—	Therms per Ton of Coal Carbonized.	Per Cent.
1	2	3
Heat supplied—		
1. Coke to producers	37·69	99·0
2. Steam to producers	0·38	1·0
	38·07	100·0
Accounted for as follows :—		
(*a*) Potential and sensible heat of waste gas outlet boiler	8·71	22·9
(*b*) Heat absorbed in raising steam in boiler	5·55	14·6
(*c*) Heat used in setting for maintaining the temperatures of the chambers (difference)	20·45	53·7
(*d*) Potential and sensible heat of total ashes and clinker	2·92	7·7
(*e*) Heating of water in tie bars	0·44	1·1
	38·07	100·0

Item (*a*) of Table IX represents the direct loss of heat up the stack. It amounted to 22·9 per cent. of the total heat supplied. Item (*b*) is the sum of the heat in the steam raised, the heat in the water blown down and the heat lost by radiation and convection from the surface of the boiler, less the heat in the feed water. Item (*d*) gives the heat accounted for by the ashes and clinker, and (*e*) the heat which was absorbed by the boiler feed water in circulating through the tie bars.

Item (*c*) is a difference item which gives an indication of the amount of heat used to maintain the temperatures in the setting, *i.e.*, the heat which passed from the combustion flues through the chamber walls into the charge, plus the loss by radiation and convection, &c. The figure is somewhat lower than the true quantity since no account has been taken of the heat obtained by the combustion of the gases and vapours leaking from the chambers. An allowance for this additional source of heat would increase the figure given above, namely, 20·45, by approximately 1·5 therms.

Table IX above shews that more than half of the heat in the coke and steam supplied to the producers, passed through the chamber walls. The magnitude of this proportion is a main factor determining the coke consumption in the producers. It depends to a considerable extent on the amount of heat which is absorbed by the secondary air in passing through the recuperators, and which is brought back and made available in the combustion flues. After the Test, a determination of the temperature attained by the secondary air in passing through the recuperators, showed 700° C. to be a typical value. From this figure and the volume of the secondary air, it can be calculated that the amount of heat returned to the combustion flues in this way was approximately 5·8 therms per ton of coal carbonized, an amount equivalent to 28 per cent. of that part of the heat of the fuel which is utilized in the setting.

The heat absorbed by the coal charge during carbonization is accounted for by heat absorbed in reactions and decompositions, sensible heat in gases and vapours, and sensible heat in the hot coke as it is discharged from the chambers. Since the loss of sensible heat in the coke on an intermittent plant is considerably greater than the corresponding loss in continuous vertical retorts, it is interesting to estimate what fraction of the total heat passing into the chambers is accounted for in this way. Assuming that the coke was discharged at 900° C., the sensible heat it contains relative to 15° C. was 9·5 therms per ton of coal carbonized, or 45 per cent. of the heat passed into the chambers. The reason why this loss does not lead to a higher fuel consumption lies largely in the high performance of the recuperators on the waste gas stream.

The Steam Raised in the Waste Heat Boiler.

As would be expected from the low fuel consumption in the producers, and from the recuperation of waste heat which had occurred before the waste gases entered the boiler, the amount of steam raised was comparatively low; this is in effect a testimony of the heat recovery in the setting proper. The steam raised amounted to 464·8 lbs. per ton of coal carbonized, or 1·59 lbs. per lb. of dry coke supplied to the producers.

The boiler pressure was approximately 110 lbs. per sq. in., and all the steam, excepting that supplied to the producers, was superheated to a temperature of 540° F. The steam to the producers, which represented 7·8 per cent. of the output of the boiler, was supplied saturated.

Thus, with a feed water temperature of 163° F., the Equivalent Evaporation of the boiler from and at 212° F. was 548 lbs. per ton of coal carbonized, or 1·87 lbs. per lb. of dry coke supplied to the producers.

The steam raised was accounted for as shewn in Table X, below.

TABLE X.—*Steam Raised and Used.*

Total steam raised, lbs. per ton of coal carbonized		464·8
Steam supplied to producers, ,, ,, ,,	36·4	
Steam supplied to chambers, ,, ,, ,,	75·6	
Steam supplied to turbine, ,, ,, ,,	150·7	
Steam to auxiliary plant and surplus, ,, ,,	202·1	
		464·8

Electrically driven plant included that for unloading, crushing, and elevating the coal, the coke handling plant, quenching water pumps and circulating liquor pumps. It was found that the total electrical current used was 2·045 kilowatt-hours per ton of coal carbonized.

In Table IX, the sum of items (*a*) and (*b*) represents the heat in the waste gas entering the boiler, and equals 14·26 therms per ton of coal carbonized. The heat in the steam raised in the boiler was 5·34 therms, and hence the efficiency of the boiler was 37·4 per cent.: 61·1 per cent. of the heat in the waste gases at the boiler inlet passed up the stack.

The efficiency of the boiler is low because of the comparatively low temperature at which the gases enter it, namely, 573° C., and also as a result of the considerable proportion of the heat in the waste gases which was latent as water vapour.

The greater proportion of the moisture in the waste gas came from the water and steam supplied at the producer grate, but 35 per cent. of it was due to the moisture in the coke supplied to the producers. This moisture passed forward into the producer gas without under-

going any considerable decomposition in the fire. In addition to diluting the gases in the combustion chambers, it absorbed heat from the producers in its evaporation, which heat passed forward in the gases as latent heat, not recoverable in the boiler. The percentage of moisture in the producer fuel was 34·3 per cent. on the dry basis. The evaporation of this moisture required 1·13 therms per ton of coal carbonized, *i.e.*, 3 per cent. of the heat of combustion of the coke supplied to the producers, or 12·9 per cent. of the loss up the chimney.

The Efficiency of Gas Production and of Carbonization.

Apart from the small amounts of electrical energy used, the sole source of heat for the whole process of carbonization was the potential heat of the coal supplied, since the plant met its own fuel and steam requirements. The heat of the coal was accounted for by the potential heats of the gas, the tar, and the coke for sale, together with the heat used and lost in carbonization.

The heat in the amount of steam raised above that required for the ovens, producers, and auxiliary plant is neglected. The steam requirements of the auxiliary plant, other than the turbo-fan, were not measured, but it can be estimated that the heat in the surplus steam was not greater than 0·5 therm per ton of coal carbonized, *i.e.*, 0·15 per cent. of the total heat supplied to the plant, and against this can be set the consumption of the electrically driven plant.

The heat used and lost in carbonization includes the heat in the coke supplied to the producers, and the loss of potential heat during charging, discharging, scurfing, &c. These various items are given in Table XI, below.

TABLE XI.—*Efficiencies of Gas Production and Carbonization.*

Heat Supplied.	Therms per Ton of Coal Carbonized.
(1) Coal	311·7
Accounted for as follows :—	
(*a*) Gas	78·7
(*b*) Tar	24·4
(*c*) Coke for sale	162·8
(*d*) Heat used and lost in carbonization (difference)	45·8
	311·7

The Efficiency of Gas Production equals 63·2 per cent when expressed as the heat in the gas, divided by the sum of the heat in the gas *plus* the heat used and lost in manufacture, *i.e.*,

$$\frac{\text{Item } a}{\text{Item } a + \text{item } d}$$

The Efficiency of Carbonization equals 85·3 per cent., and is given by the sum of the potential heats in the products, gas, tar, and coke for sale, divided by the total heat supplied as coal, *i.e.*,

$$\frac{\text{Item } a + \text{Item } b + \text{Item } c}{\text{Item (1)}}$$

The Leakage from the Chambers.

Loss of water gas during the steaming period was inappreciable; loss of coal gas was 1·6 therms per ton of coal carbonized. It is believed that these losses are less than those of average practice and are factors contributing to the satisfactory yield of gas.

The leakage from the chambers clearly depends to a considerable extent on the gas pressures developed inside them. It is interesting to note that different coals varied widely in their behaviour in this respect. Thus it was found, that with some coals, gas continued to be evolved from the liquor-sealed bottom offtake up to the eighth hour of carbonization, whereas with others, the gas flow through the bottom offtake ceased after the second hour.

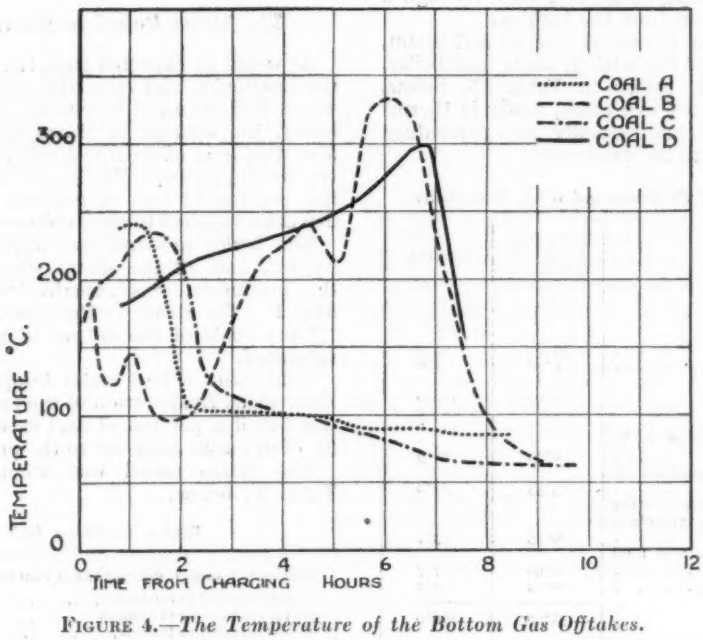

FIGURE 4.—*The Temperature of the Bottom Gas Offtakes.*

These differences in behaviour are apparent in Figure 1, above, which shews the temperature in the bottom offtake plotted against time. Thus, in spite of the regulation by the retort house governor, the pressure at the base of the chamber can, for a considerable proportion of the time, be greater than the seal on the bottom offtake, namely, 1½ ins. water gauge.

The total loss of carbon in the whole process of carbonization was obtained by the preparation of chemical balances.

The loss was equivalent to 1·7 per cent. of the carbon supplied to the chambers as coal and coke. Of this amount, 0·3 per cent. was accounted for by leakage to the combustion flues and 1·4 per cent. by losses, (1), during the charging and discharging of the chambers and the quenching of the coke; (2), as scurf; and (3), by small leakages of gas from the chambers other than that to the combustion flues, *e.g.*, from doors, cleaning of offtakes, &c.

23rd Report of the Refractory Materials Joint Sub-Committee

WORK CARRIED OUT BY THE BRITISH REFRACTORIES RESEARCH ASSOCIATION.

(1) The Hot-Patching of Gas Retorts.

Part I. Preliminary Experiments on the Application of Certain Cements.

By F. H. Clews, M.Sc., A.I.C., H. Booth, and A. T. Green, F.I.C., F.Inst.P.

Notes on Current Practice.

Three types of procedure for the use of patching cements appear to be in current use. These are:—

(1) The application of the cement in a pasty or plastic condition by means of a long-handled iron paddle or trowel;
(2) spraying the affected surface with a cement wash;
(3) the utilization of an adapted form of shot or air gun to force a cement slurry or paste, under pressure, to the desired position.

It is not difficult to appreciate the indifferent success attending all these methods of repair, since in each case a cold wet mixture is suddenly brought into contact with a brick surface at a high temperature. The steam quickly evolved prevents satisfactory adhesion of the cement to the brickwork from the outset, and in addition there is the strain induced on the retort brickwork by the rapid local and severe temperature changes. These strains may be particularly harmful to silica settings.

It is desirable, therefore, to pay strict attention to the condition of all cold retorts before putting them again into operation, to renew the pointing and to wash the surface with a suitable silica cement. By this means the occasions on which recourse has to be made to hot-patching will be reduced. Nevertheless, at present it seems that the necessity for the process cannot be eliminated, and it is therefore of importance to investigate the means of carrying it out most effectively. The experiments described in this Report fall into two categories; those made on a variety of cement mixtures with the object of finding the types most suitable for application by existing methods, and those investigating the feasibility of using other methods of application in order to avoid the difficulties and undesirable features mentioned above.

Experiments on Cements for Application by the Paddle Method.

The essential properties for cements for application by the paddle method were considered first, as it was thought that any cement mixture which could be applied satisfactorily by the simple paddle method would also be amenable to use in the cement gun. The properties of the ideal cement for this purpose would include:—

(1) Adherence to a vertical silica brick surface from the time of application until the working temperature was acquired.
(2) The existence of a certain minimum of workability to allow of manipulation on the retort surface.
(3) A small wet-to-fired contraction or expansion so that the union with the brickwork involves the minimum of strain.
(4) The maturing of the cement at working temperatures to a compact non-friable mass.
(5) A satisfactory degree of refractoriness.

At the outset attention was directed to the first essential property, which may for convenience be termed "stickability." It was quickly apparent that cements in current use for the building of retorts were unsatisfactory for the purpose of hot-patching owing to the deficiency in this property. Accordingly the effect of additions of small amounts of organic materials was tried.

Experiments were also made on the best proportion of water to use for the preparation of the cement mixture from the point of view of ease of application. This appeared to be in the neighbourhood of 30 per cent. by weight.

It is unnecessary to describe in detail all the various proportions of the combustible additions which were tried. It will be sufficient to state that:—

(1) The addition of cellulose liquor improved the ease of application and extended the time during which the cement adhered to the bricks;
(2) An addition of about 3 per cent. of cellulose liquor appeared the most beneficial, further quantities not improving the "stickability," and being difficult to burn out;
(3) Sulphur exerted no beneficial effect;
(4) Pitch was not so effective as sulphite liquor;
(5) In every instance the cement could be dislodged from the brick surface.

The results of these tests demonstrated the usefulness of sulphite liquor for hot-patching work, but also emphasized at the same time that a jointing cement could not be transformed into a hot-patching cement by such a simple procedure. It was evident that the usefulness of the organic addition was limited to the few seconds during the actual applications, but that with the removal of the water and the burning out of the sulphite liquor some additional ingredient was required to maintain adhesion while the cement was rapidly acquiring the temperature of the brickwork. Accordingly it was sought to develop the requisite properties in the cement by two expedients.

Firstly, in an endeavour to mitigate the effect of the sudden volatilization of water from the cement a proportion of crude glycerol was added to the water used in preparing the mix. It was hoped that this would improve the working properties by extending the time during which the cement dried in position. Trials were made with proportions of glycerol in the mixing solution, varying from 50 to 10 per cent. both with the plain silica-clay cement and with the addition of sulphite liquor. An improvement in workability and initial adhesion resulted from the inclusion of the glycerol in the mixing water, but amounts in excess of 10 per cent. were of no extra value. This improvement was in addition to that conferred by the sulphite liquor. Here again it must be emphasized that really permanent adhesion was not obtained, and there was little evidence of effective union with the brickwork.

Secondly, with a view to developing cohesion of the cement with the structure, the effects of additions of limited amounts of fluxing agents were investigated.

It may be stated immediately that no real success was achieved with any of the mixtures tried, even when the amount of flux added was much in excess of the amount permissible in retort working.

Reviewing the work thus far carried out, the following conclusions seem permissible:—

(1) The major problem of "stickability" where a wet cement is applied to very hot-brick surface has not been solved, although a small amount of cellulose liquor and a proportion of glycerol in the water of the mix have been found slightly beneficial in the very early stages.
(2) The addition of fluxing agents in such an amount as to promote adhesion between, say, 400°-1000° C. is not very practicable, chiefly owing to the large reduction in refractoriness of the cement. With small amounts adhesion occurs only at a comparatively small number of points of contact.
(3) It is more difficult to apply a wet cement to a hot vitrified surface.

Experiments with a Cement Gun.

The few experiments carried out with a cement gun

were made with an adapted form of sports revolver. A pellet of the cement in paste form, wrapped in thin tissue paper, was inserted in the barrel. The pellets were fired with blank cartridges with the revolver clamped in the required position opposite the test-surface in the furnace. It was found that using the silica-prussian blue-chromic oxide mixture which had been most suitable in the previous experiments, satisfactory adhesion to the brick surface resulted, when (*a*) the water content of the cement was suitable, and (*b*) the distance from gun to target was adjusted correctly.

The conclusion that with correct adjustment a far more satisfactory union of the cement with the brickwork can be obtained by the use of a gun than by application with a paddle is of interest. The great disadvantage is the limited area that can be covered at one operation.

Experiments on the Application of Cements in the Dry State.

(*a*) *By introduction into a stream of compressed air.*

Our experiments so far do not permit us to recommend any cement mixture as being capable of successful application in paste form to a hot retort surface. Moreover, such a method of repair, even if good adhesion were obtained, must inevitably produce weakening strains in the retort structure owing to the sudden temperature fluctuations involved. These considerations led us to experiment with methods of applying the cement in the form of a dry powder. By this means the difficulties associated with the sudden evolution of steam would be avoided, even if disadvantages due to other causes were encountered.

It was possible to build up satisfactory deposits, which were of reasonably close texture, and which adhered quite well to the brickwork.

When silica bricks were used, a tendency was observed for small portions of the cement to fly off with some velocity when the test samples were practically cold. This was no doubt due to the low-temperature inversions of silica, since it was not observed with siliceous fireclay, and semi-silica materials. Our experiments were thenceforth carried out on these latter materials, as the question at issue was that of satisfactory adhesion to a hot surface. Although good deposits were obtained by this means, one difficulty encountered with the process was that of placing the deposit in the desired position, for the cement did not appear to adhere immediately opposite the delivery tube, but was connected in an obscure manner with the different gas currents and eddies produced near the brick surface, which in turn were dependent on the gas velocity and the angle of its impingement.

The compositions of the cements which gave satisfactory deposits were:—

(1) 80 per cent. silica cement, 20 per cent. iron chromate;
(2) 80 per cent. silica cement, 20 per cent. chrome ore.
(3) 82 per cent. silica cement, 18 per cent. potash felspar.

The first of these gave the best deposit, and the third, although of lower refractoriness than the second, was the least satisfactory. From these and other trials it was concluded that the cements of highest specific gravity were, under comparable conditions, the easiest to apply.

(*b*) *By introduction into a blow-pipe flame.*

It will be useful to point out a few advantages conferred by this method of application. In the first place it is possible to apply cements which normally mature at a comparatively high temperature. The question of excessive contraction or expansion of the wet-to-fired, or even dry-to-fired cement does not arise, since a certain amount of heat work is performed on the cement before it reaches the surface of application. Although a large amount of work remains to be done with regard to the cement compositions and grain sizes, as well as that of the flame temperatures, sufficient indication of the usefulness of the method has been given, provided it is possible to devise a suitable appliance for Works use. This, although requiring much thought in its design, does not appear to be impossible. A supply of coal gas and compressed air is required. The material of construction of the cementing blow-pipe would need to withstand the temperature of the hot retort. The following suggestions are offered. Firstly, possibly it could be partly or wholly constructed from heat-resisting steel; and, secondly, ordinary steel with water cooling could be used. For the best results in application the retort under repair would need to be at as high a temperature as the operator carrying out the work could bear. In order to obtain successful distribution of cement into the air-blast it might be preferable to carry out repairs to vertical retorts from the top.

(2) The Permeability of Refractory Materials to Gases.

Part IV. Experiments at Temperatures up to 850° C.

By F. H. Clews, M.Sc., A.I.C., and A. T. Green, F.I.C., F.Inst.P.

Introduction.

The present work is in continuation of that recorded in Part II[1] of this series on the Permeability of Refractory Materials to Gases in which the effect of temperatures up to 500° C. on the permeability of nitrogen of a number of fireclay and silica products was investigated. The effect of temperatures between 500° C. and 850° C. has now been examined, and the results correlated with those previously presented. The temperature of 850° C. is still considerably below that at which the majority of refractories are in service, but the nature of the apparatus and the experimental conditions imposed that upper limit. Moreover, approximate values of the coefficient of permeability at higher temperatures can be inferred from the present results.

Summary.

1. The permeability to nitrogen of thirteen representative refractory materials has been directly measured at temperatures between 500° and 850° C.

2. The permeability decreases with rise in temperature in a manner almost independent of the nature of the material and the value of its permeability coefficient at ordinary temperatures. For a temperature increase from 10° C. to 500° C., the permeability is reduced to almost 0·5 its value, and from 10° C. to 850° C. to a little below 0·4 of its value. For silica materials the values are slightly less.

3. The increase in the viscosity of the gas with rise in temperature is shown to account almost quantitatively for the decrease in permeability.

4. Assuming a quantitative relationship between permeability and gaseous viscosity, the reduction in permeability produced at 1000° C. to 1350° C. has been calculated.

(3) The Significance of Permeability to Gases in Relation to the Use of Refractory Materials in Gas Retorts.

By F. H. Clews, M.Sc., A.I.C., and A. T. Green, F.I.C., F.Inst.P.

The Gas Retort.

The gas retort of whatever type is a system enclosed by walls of refractory material in which gas is generated and maintained at a small pressure before being drawn away. Obviously upon the permeability of the material of the walls of the retort depends the amount of gas which passes through to the flues and is lost. So long as the retorts are constructed from ceramic material this loss must occur, but whether the loss is appreciable is a matter for investigation. We may gain an approximate idea of the order of this loss from existing data. For an average retort material, working under normal conditions, the calculated loss for a new installation would appear to be of the order of 0·75 per cent. and of this 0·3 per cent. apparently escapes in the upper fifth of the retort.

It is perhaps as well to stress the fact that the calcula-

[1] 22nd Report of the Refractory Materials Joint Sub-Committee of the Institution of Gas Engineers, 1931, pp. 16–23.

tion is based on the data for unused material, but after a few weeks' service the conditions obtaining in the retort will have considerably modified its properties. For instance, the lower two-fifths of the retort will have been so affected by the slagging action of the coal ash as to become almost completely glazed, and in this condition will approximate to a completely gas-tight structure. The glazing action of the slag as we proceed from the bottom towards the top become less pronounced, but in this zone there is an accumulation of scurf which also has the effect of reducing the passage of gas from the retort to the flues. There is thus left only the topmost portion through which transfer of gas can proceed to any appreciable extent. The conclusion to be drawn from the calculation, therefore, is that the 0·75 per cent. represents about the maximum loss which can occur in a retort of this description by the process of transpiration through the refractory material. It also appears probable in those instances where the transference of gas from the retort to the flues in quantities largely in excess of the above figure has been demonstrated by the analysis of the flue gases that the loss has taken place via the cracks and faulty joints produced in service rather than by passage through the intact retort walls.

Of greater moment, perhaps, than the loss caused by the penetration of gases through the retort walls is the consideration that these gases are the means of introducing corrosive material within the pores of the structure, either in the form of vapour or as fine dust particles. This action may be expected to occur more particularly in the upper half of the retort, where surface slagging is not so severe. Owing to the high temperature and the irregular nature of the connecting pore systems it is likely that these corroding agents will be retained almost completely in the pores of the retort material, in the former case by direct chemical action, and in the latter by deposition and subsequent reaction. Further, it will be recognized that it is the rate of flow of gas through the refractory, which in turn depends upon its permeability, that determines the rate at which alkalis, iron compounds, or other injurious products are brought into intimate contact with the interior pore surfaces within the retort structure.

In general we may expect, therefore, a zone, probably not far removed from the carbonizing face, comparatively rich in flux-forming oxides. Analyses have been made in various zones of vertical retort material which bear out this deduction. The extent and location of this contaminated zone will depend on several factors, but from the above it appears that the permeability of the material must be one of them. The discontinuity thus produced in the structure of the material may well cause a predisposition to flaking and spalling when subjected to the strain of the next scurfing operation, and may account in some measure for the relative mechanical weakness of a retort after operating some months in the region about 10 or 12 ft. from the top.

The fact that in all gas retorts the flue surfaces are at a higher temperature than the carbonizing surfaces is of importance in considering the question of slagging and corrosion. For if the temperature at a fluxed zone is sufficiently high for the matrix there to have more than a minimum fluidity, surface forces will induce a migratory movement, more particularly towards the flue sides of the refractory, where the temperature is higher and the fluidity of the matrix consequently greater. This consideration will apply wherever in a retort the slagging action is sufficiently well developed, and will therefore in general be restricted for the most part to the lower half of the retort. Analytical evidence has been obtained of this passage of basic oxides away from the carbonizing face in a number of vertical retorts. Indeed, in some instances, the results suggest that the matrix itself, possibly rendered more mobile by contamination, has under the influence of the temperature gradient been bodily withdrawn, to be immediately succeeded by the advancing wave front of slagging material. Now the movement of a viscous liquid through a porous structure owing to the difference in temperature on two faces is obviously a very complex process; but it is significant that a parallelism has been found, not only between permeability to gases and to liquids, but in addition to penetrability to liquids, that is, the ease with which a liquid is drawn into a porous body by capillary forces.

It would appear that the greater the permeability of the retort material in the upper half, the greater the possibility of contamination giving rise to flaking and spalling while in the lower half, the greater the readiness with which slagging constituents may be withdrawn from the carbonizing towards the flue surface. Providing the under-load strength of the structure is not seriously impaired, this may be beneficial in reducing the tendency of the charge to stick. The refractory for the upper portion of the retort should on this argument have as low a permeability as is consistent with the other requisite properties, while for the lower half a greater permeability (but not too great) might be beneficial. The consideration of the zones in which the direct loss of gas is greatest leads to the same conclusion.

In the horizontal type of gas retort the possibility of gas losses through the refractories is greater, owing to the relatively higher pressure which normally exists in the free space at the top of the retort. It may possibly assume economic proportions, particularly in the case of retorts constructed from silica materials, which as a class are more permeable than fireclay. In the horizontal, as in every type of retort, the maximum loss from this cause will occur in the initial stages of operation, because the glazing action of the slag and the deposition of scurf are quickly effective in reducing the permeability of the refractory materials.

(4) The Permeability of the Diatomite Insulating Product in Relation to its Industrial Application.

By F. H. Clews, M.Sc., A.I.C., and A. T. Green, F.I.C., F.Inst.P.

The object of this note is to draw attention to the low permeability of good heat insulating, generally diatomite, products and to point out that they serve the useful purpose not only of heat insulation but also of insulation against gas penetration.

(5) The Action of Carbon Monoxide on Refractory Materials.

Part III. Experiments (*a*) with Laboratory-Prepared Specimens, (*b*) on the Influence of Reheating Disintegrable Products.

By W. Hugill, M.Met., F.R.M.S., H. Ellerton, and A. T. Green, F.I.C., F.Inst.P.

Introduction.

In previously reported work it has been clearly demonstrated that certain types of " iron spots " are the centres around which the disintegration of firebricks under the influence of carbon monoxide at 420° C. takes place. Further, on the basis of this experimental work, it was suggested but not proved that the " iron spots " which promote the deposition of carbon contain free " iron oxide," whereas in the " iron spots " of materials resisting disintegration the iron oxide has entered into combination with the constituents of the fired clay. With the object of obtaining more information on this matter the present investigations with laboratory-prepared specimens were commenced.

The Specimens.

The specimens were fired cylindrical test pieces moulded to a size of $1\frac{1}{4}$ in. by $\frac{1}{2}$ in. from non-ferruginous clays to which additions of different iron-bearing substances had been made. Three clay mixes of

(*a*) ball clay;

(*b*) china clay; and

(*c*) ball clay with 15 per cent. grog (40-80's mesh in size and fired at 1200°)

formed the bases of the three batches. The clays were

sieved through an 80's mesh sieve. Four types of ferruginous additions were used, namely:—

(1) hæmatite;
(2) magnetite;
(3) pyrites; and
(4) iron oxide-clay mixtures, sintered and fused at high temperatures.

These ferruginous substances were added on the basis of 2 per cent. and 5 per cent Fe_2O_3.

The firings, which were conducted in a small laboratory muffle, were:—

Firing (1) – up to 1000° C. in 8 hours;
Firing (2) – firing (1) + up to 1250° C. in 9 hours;
Firing (3) – firing (1) + up to 1380° C. in 11 hours;
Firing (4) – up to 1250° C. in 9 hours;
Firing (5) – up to 1380° C. in 11 hours.

The specimens after firing were carefully sorted for blemishes. One hundred and twenty types of test pieces were thus made, the variables being:—

(*a*) the nature of the clay basis;
(*b*) the amount of "iron" addition;
(*c*) the nature of the "iron" addition; and
(*d*) the firing treatment.

The chief inferences to be obtained from the results may be summarized as follows:—

(1) On an average, the order of potency of the four ferruginous additions causing disintegration is:—
   (*a*) hæmatite;
   (*b*) magnetite;
   (*c*) pyrites;
   (*d*) iron oxide-clay fusion.

   Thus, the effect of the hæmatite is greatest and that of the iron oxide-clay fusion by far the least pronounced of the four substances.

   Pyrites has more influence in specimens of low temperature firing than in those fired at the higher temperatures. This is probably connected with the composition of the pyrites used, which contained some silica. At the higher temperature, probably, more ferrous silicate was formed from the pyrites addition.

(2) The average effect of increasing the temperature of firing is to increase the resistance to disintegration. Firing to 1380° C. in these experiments. although greatly reducing the disintegration tendency for all the specimens does not entirely eliminate it. It is noticeable that the deposition of soot still occurs in a number of the specimens fired to this temperature. It is further interesting to note that a greater degree of disintegration takes place with those specimens fired directly to 1250° C. (firing 4) than with those fired to 1000° C. (firing 1). This observation, which is particularly noticeable with the specimens containing the iron oxide-clay fusion, is probably connected with the influence of temperature on the character of the iron compounds.

(3) No definite conclusions respecting the effects of the different basic clay mixtures can be drawn.

(4) The effect of the 5 per cent. additions is obviously more pronounced than that of the 2 per cent. additions.

The Influence of Reheating Disintegrable Products.

The examination of the "iron spots" suggested that the finishing temperature of firing and the time spent on the high-temperature soaking of the products probably influenced considerably the disintegrating tendency. With the object of studying this suggestion, test samples of a product which normally showed disintegration in 10 hours or less were heated in a laboratory furnace to temperatures of 1200°, 1320°, and 1400° C., and held at these temperatures for 4 hours. These three sets of specimens were afterwards tested for their resistance to the action of carbon monoxide at 500° C. In each case this power of resistance had been materially increased. The specimens which had received heat treatment at 1200° C. showed a deposition of soot in the pores after 80 hours' treatment. Soot appeared after 65 hours' treatment in the specimens refired to 1320° C., but no signs of disintegration were evident. No change whatever was noted in the test pieces which had been refired to 1400° C. It is evident that this refiring treatment had considerably influenced the disintegrating tendency. It is therefore suggested that by increasing the maturing temperature and duration of soaking the products will show better resistance to the action under consideration. There is, of course, a limit to this extra firing treatment, which is determined by the nature of the original clay and the texture of the body and other properties desired in final product. It is obviously desirable to compromise, with the understanding that where possible extra heat work supplied in the maturing period will probably be beneficial in decreasing this disintegrating tendency, but disadvantageous in so far as it increases the thermal spalling tendency.

Concluding Note.

It has been clearly demonstrated in this and previous Reports that certain types of "iron spots" are the centres around which the type of disintegration under consideration takes place. An attempt has been made to give the nature of these spots greater definition. For the prevention of disintegration in those circumstances of industrial usage which include an atmosphere of carbon monoxide it is obviously desirable that the clay be carefully selected and picked before manufacture, so that the presence of ferruginous nodules may be reduced to a minimum. It is further suggested that the higher the maturing temperature, within the limits of the production of a satisfactory product, the better the resistance to the disintegration.

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GAS MARKETS & MANUFACTURES

Stock Market Report.

[For Stock and Share List, see later page.]

The new Account opened on the Stock Exchange with a fresh display of activity in nearly all markets. There were slight reactions here and there owing to profit-taking brought about by the substantial improvements which had recently taken place, but with the strong undertone prices quickly recovered any set-back. Towards the close conditions became less settled by reason of the fall in the value of the sterling exchange, and there was some decline in prices, particularly in the gilt-edged market.

The demand is so great for every kind of sound investment stock offering a slightly higher yield than that obtainable on gilt-edged securities, that Gas stocks and shares have been appealing to a much larger investing public than hitherto, the result of which can be seen in the continual upward trend of prices. Many stocks improved again last week, and among these to show the greatest increase were: Bournemouth sliding-scale with a gain of 13 points to 195; Hastings and St. Leonards, 10 points to 135; and Liverpool 4% debenture 8½ points to 96½ on the local Exchange.

The volume of business was again on the heavy side, and, judging from the transactions which have been recorded during the past week or so in those stocks rarely available, it would appear that some investors have been tempted by the present high levels to dispose of their holdings, though the reinvestment of the proceeds to give anything approaching an equivalent yield with like security must be a difficult problem at the present time.

The new 5% irredeemable debenture stock of the Commercial Gas Company is now officially quoted, and business was recorded last week at 120. It will be remembered that holders of the Company's ordinary stock have recently been given the option to exchange their holdings for the new debenture stock in the ratio of £96 5% debenture stock for £100 ordinary stock. The price of the ordinary stock is now 104½, while the value of £96 debenture stock is nearly 115¾, thus showing a substantial capital appreciation. It is understood that the offer to exchange still remains open.

New Gas issues are now appearing, and among the first of these is the issue of £850,000 4% preference stock of the South Metropolitan Gas Company which is being offered for sale by tender this week at a minimum of 101, yielding at this price £3 19s. 2d. The new stock will be irredeemable and ranks equally with the existing 6% preference stock of the Company. Another issue is that by the Mid-Southern Utility Company (formerly the Aldershot Gas, Water, and District Lighting Company) which is offering for sale by tender £60,000 5% "C" consolidated stock at a minimum price of £97 10s. per £100 stock.

Current Sales of Gas Products.

The London Market for Tar Products.

LONDON, *Oct.* 24.

There are no changes to report in the values of tar products, which are as follows:

Pitch is firm at 97s. 6d. to 100s. per ton f.o.b.

Creosote is 3½d. to 5s. per gallon f.o.b., according to specification.

Refined tar is 4d. to 4¼d per gallon in bulk at makers' works.

Pure toluole is about 2s. 7d.; pure benzole, about 1s. 11d.; 95/160 solvent naphtha, about 1s. 7½d.; and 90/140 pyridine bases, 3s. 9d. to 4s.—all per gallon naked at makers' works.

Tar and Tar Products in the Provinces.

Oct. 24.

The average prices of gas-works products during the week were: Gas-works tar, 33s. to 38s. Pitch—East Coast, 85s. f.o.b. West Coast—Manchester, Liverpool, Clyde, 85s. f.o.b.* Toluole, naked, North, 1s. 7½d. to 1s. 9d. Coal-tar crude naphtha, in bulk, North, 5½d. to 5¾d. Solvent naphtha, naked, North, 1s. 4d. to 1s. 4½d. Heavy naphtha, North, 10½d. to 11d. Creosote, *ex* works, in bulk, North, liquid and salty, 2¼d. to 2¾d.; low gravity, 1¼d.; Scotland, 2¼d. to 2¾d. Heavy oils, in bulk, North, 4¾d. to 5¼d. Carbolic acid, 60's, 1s. 6½d. to 1s. 7d. Naphthalene, £9 to £10. Salts, 55s. to 75s., bags included. Anthracene, "A" quality, 2½d. per minimum 40 p.ct., purely nominal; "B" quality, unsaleable.

* All prices for pitch are now quoted on the basis of f.o.b. In order to arrive at the f.a.s. value at any port it will be necessary to deduct the loading costs and the tolls whatever they may be.

Tar Products in Scotland.

GLASGOW, *Oct.* 22.

Orders are scarce and, in some cases, values have been marked down, although, in general, quotations are fairly steady.

Crude gas-works tar.—Actual value is easier at 45s. to 50s. per ton *ex* works.

Pitch.—This market remains firm, but supplies are not plentiful. Export value is nominal at 85s. to 90s. per ton f.o.b. Glasgow, while, in the home market, 90s. to 95s. per ton *ex* works continues to be quoted.

Refined tar to Ministry of Transport Specification is slow with value round 3¾d. to 4d. per gallon in buyers' packages *ex* makers' works.

Creosote oil.—There is little or no activity, and prices are easy. B.E.S.A. Specification is 3½d. to 3¾d. per gallon; low gravity, 3¼d. to 3¾d. per gallon; and neutral oil, 3¼d. to 3¾d. per gallon—all *ex* works in bulk.

Cresylic acid.—Conditions remain weak with prices irregular. Pale, 97/99%, is 11½d. to 1s. per gallon; dark, 97/99%, 10d. to 11d. per gallon; and pale, 99/100%, 1s. 2d. to 1s. 3d. per gallon—all f.o.r. in buyers' packages.

Crude naphtha.—Value is unchanged at 4½d. to 5d. per gallon, according to quantity and quality.

Solvent naphtha.—90/160 grade is 1s. 2d. to 1s. 3d. per gallon, and 90/190 grade 11d. to 1s. per gallon.

Motor benzole.—While business is slow, quotations are unchanged at round 1s. 4d. to 1s. 5d. per gallon f.o.r. in bulk.

Pyridines.—90/160 grade is 3s. to 3s. 3d. per gallon, and 90/140 grade 3s. 3d. to 3s. 6d. per gallon.

Benzole Prices.

These are considered to be the market prices for benzole at the present time.

	s. d.		s. d.	
Crude benzole	0 10½	to	0 11	per gallon at works
Motor "	1 6½	"	1 7	" " "
Pure "	1 10	"	1 11	" " "

Trade Notes.

Morris-Commercials at the Scottish Show.

Visitors to the Scottish Motor Show at Glasgow (Nov. 11-19) can "kill two birds with one stone," inasmuch as they will be able to inspect practically every make of pleasure car on the market and, in addition, spend some time examining the latest commercial vehicles which are exhibited in the same building. Morris-Commercials are exhibiting five different models which embody all the latest improvements, and represent exceptional value.

Gasholder Orders.

We understand from Messrs. Saml. Cutler & Sons, Ltd., of Millwall and Westminster, that a guide-framed gasholder in steel tank has just been completed by them at Jersey several weeks before contract time, which follows their claim to have carried out in record time the erection of a spiral gasholder in steel tank at Skegness, which was fully described in our issue of Aug. 10, 1932. Messrs. Cutler are now shipping materials to the order of the Shanghai Gas Company for a spiral gasholder in steel tank to be erected in Shanghai, and have in progress a guide-framed gasholder being carried out for the Bexhill Corporation Gas Department. They have also received instructions from the Brighton, Hove, and Worthing Gas Company to carry out an extension to the important coke telpherage installation erected by them a few years ago at the Portslade Works. In addition, they have just received an order for carrying out a spiral holder in steel tank of 400,000 c.ft. capacity, including piled foundations, for the Sheppy Gas Company.

Contracts Advertised To-Day.

Cookers and Fires, &c.

The Belfast Corporation Gas Department invite tenders for the supply of cookers and heating stoves, &c. [Advert. on p. 284.]

Meters.

The Belfast Corporation Gas Department invite tenders for the supply of meters. [Advert. on p. 284.]

STOCK AND SHARE LIST.

Official Quotations on the London and Provincial Stock Exchanges.

[For Stock Market Report, see earlier pages.]

Issue	Share.	When ex-Dividend.	Dividends. Prev. Hf. Yr.	Dividends. Last Hf. Yr.	NAME.	Quotations. Oct. 22. (Provincial Exchange Oct. 21.	Rise or Fall on Week.	Transactions. Lowest and Highest Prices During the Week.
£			% p.a.	% p.a.				
1,551,868	Stk.	Oct. 3	7½	7½	Alliance & Dublin Ord. ...	100—110	...	109—111½
374,000	,,	July 4	4	4	Do. 4 p.c. Deb. ...	80—90	...	...
557,655	,,	Aug. 22	7	7	Barnet Ord. 7 p.c.	132—142	...	139½
300,000	1	Oct. 17	1/9½	1/4½	Bombay, Ltd.	21/—23/-*	...	22/— 22/9
177,750	Stk.	Aug. 22	9	9½	Bournemouth sliding scale	190—200	+13	199—200
650,050	,,	,,	7	7	Do. 7 p.c. max. ...	145—155	+5	147
439,160	,,	,,	6	6	Do. 6 p.c. Pref. ...	128—133	...	...
50,000	,,	June 20	3	3	Do. 3 p.c. Deb. ...	75—80	...	...
162,025	,,	,,	4	4	Do. 4 p.c. Deb. ...	95—100	...	162
210,000	,,	,,	5	5	Do. 5 p.c. Deb. ...	120—125	...	125
357,900	,,	Aug. 22	7½	7½	Brighton, &c. 6 p.c. Con. ...	138—143	...	...
540,000	,,	,,	6½	6½	Do. 5 p.c. Con. ...	127—132	+2	129½—132
195,500	,,	,,	6	6	Do. 6 p.c. B Pref.	125—135	...	...
1,287,500	,,	Aug. 8	5	5	Bristol 5 p.c. max.	108—109[a]	+½	...
120,420	,,	June 20	4	4	Do. 1st 4 p.c. Deb. ...	94—96[a]	...	...
217,870	,,	,,	4	4	Do. 2nd 4 p.c. Deb. ...	93—95[a]	...	...
328,790	,,	,,	5	5	Do. 5 p.c. Deb.	115—120[a]	...	131—133
855,000	,,	Oct. 3	8	7	British Ord.	125—135	...	...
100,000	,,	June 20	7	7	Do. 7 p.c. Pref.	130—130	...	...
350,000	,,	—	—	—	Do. 5½ p.c. Pref. ...	107—112	...	...
120,000	,,	,,	4	4	Do. 4 p.c. Red. Deb. ...	87—92	...	...
450,000	,,	,,	5	5	Do. 5 p.c. Red. Deb. ...	105—115	...	...
160,000	,,	July 4	5	5	Cambridge 5 p.c. Deb. ...	117—122	...	...
100,000	10	May 23	6	6	Cape Town, Ltd.	7½—8½	...	...
100,000	10	Apl. 29	4½	4½	Do. 4½ p.c. Pref. ...	6—7	...	...
150,000	Stk.	June 20	4½	4½	Do. 4½ p.c. Deb. ...	90—95	...	94½
626,860	,,	Aug. 8	6	6	Cardiff Con. Ord.	102—107	...	...
237,860	,,	July 4	2½	5	Do. 5 p.c. Red. Deb.	105—110	...	...
157,150	,,	Aug. 8	6½	5	Chester 5 p.c. Ord. ...	91—96[b]	...	...
98,986	1	Oct. 17	2/-	2/-	Colombo, Ltd. Ord....	25/—30/-*	-1/-	27/—28/6
24,500	1	,,	1/4½	1/4½	Do. 7 p.c. Pref.	18/—20/-*	...	...
609,204	1	Oct. 17	-/10'90	-/11'47	Colonial Gas Assn. Ltd. Ord.	10/—15/-*	...	...
296,053	1	,,	1/2'54	1/3'30	Do. 8 p.c. Pref.	10/—15/-*	...	...
1,843,830	Stk.	Aug. 8	5½	5	Commercial Ord.	102—107	...	...
475,000	,,	June 20	3	3	Do. 3 p.c. Deb. ...	74—79	...	77½
220,272	,,	—	—	—	Do. 5 p.c. Deb. ...	118—123	...	120
807,560	,,	Aug. 8	7	7	Croydon sliding scale ...	137—142	+4½	139—142
469,590	,,	,,	5	5	Do. max. div.	95—100	...	98½
500,000	,,	July 4	5	5	Do. 5 p.c. Deb.	120—125	+3	122—124
542,370	,,	Aug. 8	10	7	Derby Con.	120—130[c]	...	...
55,000	,,	July 4	4	4	Do. 4 p.c. Deb.	75—85[c]	...	...
209,000	,,	Sept. 5	5	5	East Hull Ord. 5 p.c. ...	95—100	+2	...
179,500	,,	Aug. 22	5½	6	East Surrey Ord. 5 p.c. ...	108—118	...	...
155,919	,,	June 20	5	5	Do. 5 p.c. Deb. ...	117—122	...	...
1,002,180	,,	Sept. 19	†6½	†5	European, Ltd.	122—127	...	123—126
19,405,992	,,	Aug. 8	5⅝	5⅝	Gas Light & Coke 4 p.c. Ord.	24/—26/-[f]	+-/6	24/7½—25/4½
2,600,000	,,	,,	3⅜	3⅜	Do. 3½ p.c. max.	78—83	...	81½—83
4,477,106	,,	,,	4	4	Do. 4 p.c. Con. Pref. ...	100—103	+2	100—102
6,102,497	,,	June 20	*3	3	Do. 3 p.c. Con. Deb. ...	80—83	+1	80½—82½
9,642,770	,,	,,	5	5	Do. 5 p.c. Red. Deb. ...	110—115	...	...
3,500,000	,,	,,	4½	4½	Do. 4½ p.c. Red. Deb. ...	110—114	+½	111½—112½
264,011	,,	Aug. 22	—	6	Harrogate New Cons. ...	104—109	...	...
82,500	,,	Aug. 22	7	7	Hastings & St. L. 5 p.c. Conv.	130—140	+10	...
258,740	,,	,,	5½	5½	Do. 3½ p.c. Conv.	100—105	...	...
70,000	10	Oct. 17	†10	†10	Hongkong & China, Ltd. ...	9½—10½*	-½	...
213,300	Stk.	Aug. 22	6	6	Hornsey Con. 3½ p.c. ...	112—117	...	...
5,600,000	,,	June 6	15	14	Imperial Continental Cap.	195—205	-5	197½—207
223,180	,,	Aug. 8	3½	3½	Do. 3½ p.c. Red. Deb.	90—95	+3	90¾—93½
285,242	,,	Aug. 8	8½	8½	Lea Bridge 5 p.c. Ord. ...	142—152	...	...
2,145,907	,,	Aug. 22	6	6	Liverpool 5 p.c. Ord. ...	113—115[b]	+2	...
245,500	,,	June 20	5	5	Do. 5 p.c. Red. Pref. ...	100—110[b]	...	...
306,083	,,	July 15	4	4	Do. 4 p.c. Deb. ...	94—99[b]	+8½	...
165,736	,,	Sept. 5	10	8	Maidstone 5 p.c. Cap. ...	155—165	+5	...
56,176	,,	June 20	3	3	Do. 3 p.c. Deb. ...	69—74	+4	70—71¾
75,000	5	June 20	†10	†10	Malta & Mediterranean ...	7½—8½	...	8½
392,000	—	Oct. 1	5½	5½	Metropolitan (of Melbourne) 5½ p.c. Red. Deb.	97—102	...	...
171,978	Stk.	Sept. 5	5	5	M. S. Utility "C." Cons. ...	92—97	...	...
718,657	,,	,,	4	4	Do. 4 p.c. Cons. Pref.	82—87	...	...
112,126	,,	July 4	4	4	Do. 4 p.c. Deb. ...	90—95	+3	...
148,955	,,	,,	5	5	Do. 5 p.c. Deb. ...	105—110	...	...
675,000	,,	21 May '31	†6	†6	Montevideo, Ltd.	30—50	...	...
2,061,315	,,	Aug. 8	5½	5	Newcastle & Gateshead Con.	21/—22/-d/	+1/-	...
682,856	,,	,,	4	4	Do. 4 p.c. Pref. ...	90½—91½d	...	...
691,705	,,	June 20	3½	3½	Do. 3½ p.c. Deb. ...	89—91d	...	...
277,285	,,	Apl. 29	5	5	Do. 5 p.c. Deb. '43...	105—107d	...	...
274,000	,,	Aug. 8	5	5	Newport (Mon.) 5 p.c. max.	91—93[a]	+5	...
199,940	,,	Aug. 22	7½	7½	North Middlesex 6 p.c. Con.	135—145	...	142½—145
396,160	,,	Aug. 8	5	5	Northampton 5 p.c. max. ...	96—101	+1	...
300,000	,,	Apl. 18	9	7	Oriental, Ltd.	85—95	...	...
205,162	,,	June 20	8	8	Plym'th & Stonehouse 5 p.c.	142—152	...	150
504,416	,,	Aug. 22	8	8	Portsm'th Con.Stk. 4 p.c.Std.	142—152	...	...
241,446	,,	,,	5	5	Do. 5 p.c. max. ...	97—102	...	...
114,000	,,	Aug. 8	5	5	Preston 5 p.c. Pref.	100—105	...	...
686,312	,,	July 18	4	4	Primitiva 4 p.c. Rd. Db. 1911	75—80	...	...
399,313	,,	June 20	4	4	Do. 4 p.c. Cons. Deb.	76—81	...	...
150,000	10	Sept. 19	6	6	San Paulo 6 p.c. Pref. ...	62—72*	...	...
1,786,968	Stk.	Sept. 5	6	6	Sheffield Cons.	110—114[e]	...	...
95,000	,,	July 18	4	4	Do. 4 p.c. Deb.	92—96[e]	...	...
133,201	,,	Sept. 5	5	8½	Shrewsbury 5 p.c. Ord. ...	113—118	...	117½
90,000	10	June 6	†5	†5	South African	4—6	...	...
6,709,895	Stk.	Aug. 8	7	5	South Met. Ord.	117—122	+2	116—122
1,135,812	,,	,,	6	6	Do. 6 p.c. Irred. Pf.	138—143	+3	140—142½
1,895,445	,,	July 4	3	3	Do. 3 p.c. Deb. ...	79—82	...	81½—82
1,000,000	,,	July 18	4	5	Do. 5 p.c. Red. Deb.	109—114	...	114
91,500	,,	Aug. 8	8½	8½	South Shields Con.	184—186[d]	...	...
1,543,795	,,	Aug. 8	6	6	South Suburban Ord. 5 p.c.	113—118	...	...
300,000	,,	,,	5	5	Do. 5 p.c. Pref.	110—115	...	113
668,337	,,	June 20	5	5	Do. 5 p.c. Deb.	120—125	...	122—123½
647,740	,,	Aug. 22	5	5	Southampt'n Ord. 5 p.c. max.	93—98	...	...
121,275	,,	June 20	4	4	Do. 4 p.c. Deb.	95—100	+3	97
350,000	,,	Aug. 8	—	9/-	Swansea 5½ p.c. Red. Pref.	102—112	...	...
200,000	,,	June 20	6½	6½	Do. 6½ p.c. Red. Deb.	105—110	...	...
1,076,490	,,	Aug. 8	6½	6½	Tottenham and District Ord.	130—135	...	...
300,000	,,	,,	5½	5½	Do. 5½ p.c. Pref. ...	115—120	...	123
199,005	,,	June 20	4	4	Do. 4 p.c. Deb. ...	95—100	...	...
85,701	,,	Sept. 19	6	6	Tuscan, Ltd., 6 p.c. Red. Db.	67—72	...	...
346,069	,,	Aug. 22	7	7	Uxbridge, &c., 5 p.ct. ...	130—140	+2½	...
88,380	,,	,,	5	5	Do. 5 p.c. Pref. ...	110—115	...	115
1,322,220	,,	July 4	7	7	Wandsworth Consolidated	130—140	...	...
971,378	,,	,,	5	5	Do. 5 p.c. Pref.	112—117	+2	116
1,167,954	,,	June 20	5	5	Do. 5 p.c. Deb.	120—125	...	124½
158,400	,,	Aug. 22	6g	5	Winchester W.&G.5p.c.Con.	98—103	...	...

Quotations at:—*a.*—Bristol. *b.*—Liverpool. *c.*—Nottingham. *d.*—Newcastle. *e.*—Sheffield. *f.*—The quotation is per £1 of stock. *g* Paid £3, including 10s. on account of back dividends. * Ex. div. † Paid free of income-tax. ‡ For year.

(This announcement is inserted gratuitously.)

PETER—WITH ONE EXCEPTION

With one exception Peter is an ordinary little fellow. Chubby, likeable, just five-and-a-half, full of life and fun and on occasions—be it admitted—of naughtiness.

Just now Peter's rather important, for this is his first term at school, and he's grappling with the intricacies of "A B C" and "Twice Two": difficult subjects to all men of five-and-a-half, but even more difficult in Peter's case because—bad luck—he's totally blind. That's his One Exception.

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Will you help with a donation or annual subscription? Any sum, large or small, will be gratefully received.

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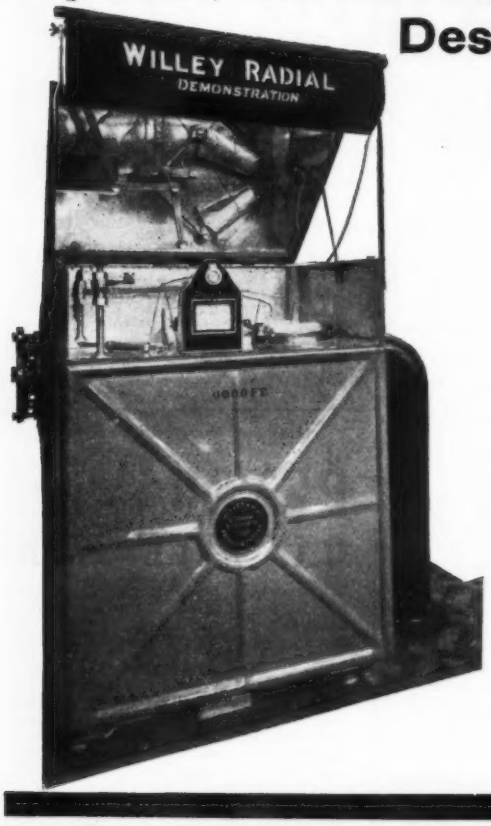

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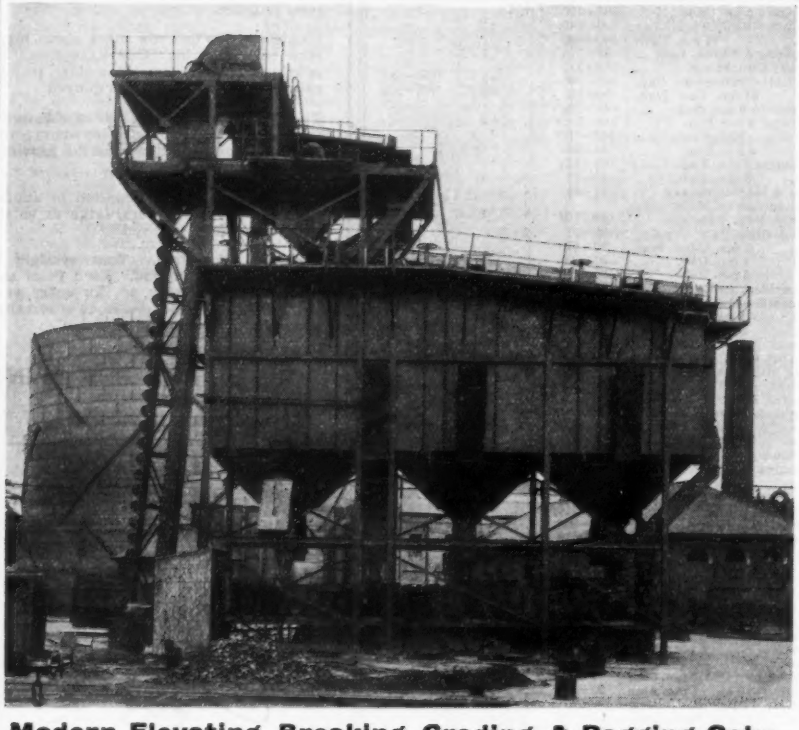

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